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ORIGINAL ARTICLES.

I.—On the Structure of the Frontal Spine and the Rostro-labial Cartilages of *Squaloraja* and *Chimæra*.

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(PLATE XII.)

THE remarkable frontal spine of *Squaloraja* has always been described as a dermal structure by those who have referred to it, and has been classed with the shagreen-granules and dentition. After the systematic position of the genus had been determined,[1] its frontal spine was rightly recognized as identical with the spine-like frontal process in *Chimæra* and fossil Holocephala, with which it was formerly compared by W. Davies[2] and A. S. Woodward.[3] Both these processes were regarded as dermal structures by von Zittel,[4] Jaekel,[5] and A. S. Woodward,[6] and treated as true ichthyodorulites, *i.e.* as if consisting of dentine or vasodentine. In 1890 the present writer briefly pointed out[7] that the frontal spine of the Jurassic Chimæroid, *Ischyodus avita*, consisted of extremely calcified fibro-cartilage, resembling that of the so-called "claspers" of all male Elasmobranchs. The microscopical structure of these parts differs conspicuously from that of the calcified granules in the common (hyaline) cartilage of the internal skeleton, and its ontogenetic development is different.

It is necessary to describe these differences in detail, because O. Jaekel[8] refers to the frontal spine as having the same structure as the rostral prolongation. With regard to the rostrum he says—"It consists of a hollow calcified tube, the peripheral parts of which consist of little fused cones on which separate star-shaped dentine-scales are fixed."[9] The following pages will show that this statement cannot be based upon accurate observations. They relate to two

[1] A. S. Woodward, Cat. Foss. Fishes Brit. Mus., pt. ii, p. 40 (1891).
[2] W. Davies, Geol. Mag., Vol. IX, p. 145, pl. iv (1872).
[3] A. S. Woodward, Proc. Zool. Soc. 1886, p. 527.
[4] K. A. von Zittel, Handb. Palæont., vol. iii, p. 95.
[5] O. Jaekel, Sitzungsb. Gesell. naturf. Freunde, Berlin, 1890, pp. 120, 127.
[6] A. S. Woodward, *op. cit.* 1891, p. 40.
[7] O. Reis, Geognostische Jahreshefte, 1890, p. 8.
[8] O. Jaekel, Die Selachier vom Monte Bolca (Berlin, 1894).
[9] "Es besteht aus einer hohlen Kalkröhre deren peripherische Teile aus zusammengeschmolzenen Kügelchen bestehen, worauf vereinzelt sternförmige Dentinschuppen sitzen" (*op. cit.*, p. 65).

interesting fragments of the frontal spine and rostrum of *Squaloraja*, duplicate specimens from the British Museum, kindly lent to the present writer for study by Dr. Henry Woodward, Keeper of the Geological Department.

The fragment of a frontal spine shown from the ventral aspect in Pl. XII, Fig. 4, exhibits at the proximal end some interesting features, which were revealed on extrication from the enveloping matrix. The expanded proximal end is small, of triangular shape, and slightly excavated on the ventral side, this excavation being subdivided by a little median crest. As long ago supposed by W. Davies, this feature indicates the insertion of two muscles, one on either side of the median crest. He pointed out that most probably the coarsely fibrous structure of the crest on the dorsal surface of the spine proved the attachment of muscular tissue, "which connected it with and served to elevate the spine above." On a male specimen of the living *Chimæra* (Pl. XII, Fig. 8) I have observed that the highest tendons of the superficial portion of the adductor mandibularis (Levator anguli oris—term)[1] are attached not only on the anterior surface of the free, upwardly-curved, proximal portion of the spine-like process, but also that the fibres of its deeper portion are connected with the whole ventral surface so far as there is space for their insertion. A branch of the tendon is attached also to the under surface of the skin covering the spine. These muscles tend to depress the spine, but there is none to elevate it. The round free process, quite separate from the cranium, is held in place by two dorsal tendon-like ligaments instead of muscles, and these reach from the dorsal surface of the proximal expansion of the spine to the prominent supra-orbital roof of the cranium (Pl. XII, Fig. 8). These tendons and the bundles of muscular fibres on the other side in *Squaloraja* could only have served to fix the spine when pressed in attack, which explains why free tubercles of the integument are confined to the lateral and dorsal side of the proximal portion of the spine.

As regards the internal structure of the frontal spine, we must remark first that it is hollow (Pl. XII, Fig. 5), but becomes more and more compact proximally. As in *Chimæra* (Pl. XII, Fig. 12), the dorsal wall of the cavity is much thinner than the ventral wall. In transverse section (Fig. 5) we may observe with a lens a number of capillary canals in the thick calcified wall; and two smaller main canals can be seen perforating the whole length of the spine, one on either side.

The microscopical structure of the spine is quite the same as in *Ischyodus* and *Chimæra*. A number of vascular canals are to be seen, and between these there are large cells. The elongated form of the cells is observed especially in the longitudinal section, and they differ usually from the cells in the prismatic granules of the calcified hyaline cartilage of the internal skeleton of Elasmobranchs, especially from those of the Holocephala. They are irregularly arranged, and the intercellular tissue is fibrous, but this never

[1] B. Vetter, Jena Zeitschr. f. Naturw., vol. xii, p. 441.

exhibits the irregular peripheral lamellation which is often observable in the lines along which the cells of calcified hyaline cartilage are disposed.[1] This microscopical structure is identical with that of the claspers of fossil and living Plagiostomes and Holocephala,[2] in which the vascular canals are only seldom wanting. The microscopical structure of the middle cone of Selachian vertebræ and of the calcified gill-filaments in the Teleostomous fishes, is also similar. The structure is, indeed, to be defined as fibrous cartilage, or, more technically speaking, as a prochondral differentiation of the mesoderm, of which the intercellular substance ("Bindesubstanz") has not yet undergone the change into the later hyaline stage.

The fibrous cartilages of the male appendicular skeleton are produced in the corium by scleroblasts of a kind which never form hyaline cartilage in fishes. They are developed in dermal folds, originally unconnected with the endo-skeleton of the pelvic fin, and only joined secondarily with the latter.[3] The frontal spine of Chimæroids is similarly quite separate from the cranium, and essentially a part of the fibrous and vascular layer of the cutis.

The cells of these calcifications, which we must now term "cutaneous," are not only irregularly elongated, but are also much more numerous than in the cartilages of the endo-skeleton. I have already pointed out[4] that there is a remarkable difference in the number of cells exhibited by fossilized fibrous cartilage and hyaline cartilage; the cells very frequently disappear entirely in the latter, and are only rarely seen in certain parts of its calcifications. I have observed the same phenomenon in the superficial granules of the endo-skeleton in the living *Chimæra*, which agrees with the fossil *Ischyodus*, *Chimæropsis*, and even with *Squaloraja*. The difference may be observed in the fibrous and hyaline cartilage of one and the same specimen.

The second British Museum specimen under consideration (Pl. XII, Fig. 1) exhibits the great median rostral prolongation. Its dorsal and ventral layers of calcareous prismatic granules are slightly displaced at the ends. On the surface are scattered several of the little hooked dentine tubercles, lying with their radiated bases upon the prismatic granules of the calcified hyaline cartilage; and these seem to be in a perfectly natural position. Near the lateral border of the proximal end of the rostrum, there is also a noteworthy lamellar deposit of bone-like substance. The bony aspect and yellowish-grey colour of this are suggestive of the proximal end of the male spine, of which the deposit may perhaps be a few splints. A microscopical section of the substance confirms this idea, and clearly shows calcified cutaneous fibrillar cartilage. The specimen may thus be either (i) the dorsal aspect of the rostrum of a male with rudiments of a spine, or (ii) the ventral aspect of such a rostrum showing paired ventral spines, or (iii) the dorsal aspect of the rostrum of a female. The latter supposition seems most probable, and I regard the specimen

[1] W. C. Williamson, Phil. Trans. 1851, pl. xxx, fig. 30.
[2] J. Riess, Palæontogr., vol. xxxiv, pl. ii, fig. 12 (clasper of *Chimæra*).
[3] Petri Zeitschr. f. wiss. Zool., xxx, 1878, p. 325.
[4] O. Reis, Mikroscop. Archiv., vol. xli, p. 569.

as proving that the spine consists primitively of paired elements, a conclusion also suggested by the bilaterally symmetrical disposition of the blood-vessels in the wall of the spine of the adult male *Chimæra* and *Squaloraja*.

This result is interesting in view of the present writer's former expression of belief that the three pairs of parietal spines of *Menaspis* (Fig. 9, ph_{I}, ph_{II}, ph_{III}) are the paired serial homologues of the azygous frontal spine of the male Holocephala. Jaekel[1] has referred these horn-like spines to the vasodentine skeleton, at the same time including the frontal spine of Holocephala among vasodentine ichthyodorulites.

The disposition of the dermal vasodentine plates in *Menaspis* as compared with the parietal horns, agrees with that of the paired plates of the Myriacanthidæ (e.g. *Chimæropsis*, Fig. 3) as compared with their frontal spine. A Myriacanthid spine with overlying tubercles is shown in Fig. 11, and may be compared with Fig. 9, which exhibits the left half of the cranium and trunk in *Menaspis*, with the three parietal (male) horns, the lateral spine, and the flat conical plates behind. Jaekel may have been led to identify vasodentine in the parietal horns of *Menaspis* (if he has had occasion to study satisfactory microscopical sections of splints of them) by the abundant occurrence of canals for blood-vessels, which are also observable in the male frontal spine of *Chimæra*, *Ischyodus*, and *Squaloraja*.

We come now to the consideration and restoration of the rostro-labial appendages of *Squaloraja*. Before having established the systematic position of the genus, A. S. Woodward described its great rostral prolongation as an "intertrabecular cartilage." Now we must regard it as identical with the corresponding cartilage in *Chimæra* (Fig. 8), and the lateral cartilages, which A. S. Woodward terms "prepalatine," will also be seen to be the same as in the last-mentioned genus. The rostrum of the Selachian *Rhinobatus maronita*, however, is nearly identical with that of *Squaloraja*.[2]

Finally, there are the labial cartilages of *Squaloraja*, of which A. S. Woodward recognizes two pairs (Fig. 6, *a*, *b*), comparing them with the rods which form the axes of the oral barbels in the Myxinoids. According to the new view, it is now necessary to compare them with the labials of *Chimæra*.

These appendages of *Chimæra* are insufficiently described by Hubrecht,[3] and it is therefore necessary to treat of them more in detail. Three segments of cartilages may be distinguished in the labial complex. The first segment (I) is a single cartilage ("nasal wing cartilage" of Hubrecht), fixed in the common rostro-labial connective tissue, which also supports the great median cartilage of the second segment. The latter consists of three cartilages, of which the great median piece II*a* is covered throughout its whole length by the *labialis anterior* muscle,[4] and thus cannot be a "Schnauzen-

[1] O. Jaekel, Sitzungsb. Gesell. naturf. Freunde, Berlin, 1890, pp. 119–131.
[2] See Catal. Foss. Fishes Brit. Mus., pt. i, pl. iii, fig. 4.
[3] A. A. W. Hubrecht, Niederländ. Archiv., vol. iii, pp. 255–272 (1876).
[4] B. Vetter, Jena Zeitschr. f. Naturw., vol. xii, p. 443 (1878).

knorpel" (Hubrecht), but can only be interpreted as part of the great upper labial cartilage L_1 of the Selachians, segmented because the *labialis* is removed from the internasal crest and attached only to the labial cartilage (II*a*-II*b*) itself. The first segment is homologous with the anterior upper labial L_1, while the lower labial cartilage of the Selachian is represented in *Chimæra* by III*a* and III*b*. Hubrecht describes the latter as hinder upper labials, retaining the symphysial cartilages of the mandible as lower labials; but, in the present writer's opinion, the latter are homologous with the "submental" cartilages in *Scyllium* and *Pristiurus*,[1] and therefore Vetter is right (*loc. cit.*) in determining III*a* and III*b* as lower labials. If one extends transversely the folded lip of *Chimæra* (Pl. XII, Fig. 7) by raising the skin at the corners of the mouth, the internal aditus of the mouth in these corners is found to curve in the direction of the arrow in Fig. 7. As a consequence the cartilages III lie in the ventral and hinder half of the labial skin-fold, shown in perspective from the anterior or inferior aspect in Fig. 7. Moreover, the attachment of the cartilages III is really on the outer surface of the mandible. The separation of the inner cartilaginous segments II and III is also indicated externally by a little infolding of the skin, which arises from a certain point of the outline of the upper lip and extends to the articulation of II and III. A recurved cartilage II*b* extends from the cartilage II*a* to this point of the outline (termed by Hubrecht the whole "anterior labial"), to support the great curtain-like lip. On its connection with II*a* is to be observed II*c* in articulation with III.

In determining the homologies of these parts in *Squaloraja*, it is necessary to remember that we are dealing with a depressed skull instead of one that is laterally compressed. Thus we recognize in the great transverse cartilage II*a* the homologue of the largest cartilage in the labial complex of *Chimæra*. Further, there may be observed at its distal end the cartilage II*c*, reflected backwards to the mouth-opening, and possibly the distal support of a similar curtain-like naso-labial fold. With regard to the third cartilage in this region in *Squaloraja*, we know that it is attached to the hinder side of the two first-mentioned labials, curved in a similar manner and probably situated in nearly the same plane as these. Hence this element can only represent the anterior labial I of *Chimæra*, lying behind the labials II in *Squaloraja* and approaching the mouth-opening on the ventral side, situated behind the labials I and the teeth. The nasal capsules, I suppose, lie between the rostral cartilage and the proximal ends of these labials, opening ventrally.

These cartilages of *Squaloraja*, therefore, cannot be regarded as cirri-like outgrowths of the hinder labials, but represent, in fact, the upper anterior and posterior labials themselves, lying apparently in the interior of a naso-labial fold. Their great development corresponds, indeed, with that of the rostrum and of the rostral spine.

With reference to the spine, A. S. Woodward observes that "we are concerned with an admirable illustration of the principle, that

[1] C. Gegenbaur, Untersuch. vergl. Anat. Wirb., pt. iii, p. 206.

the contours of superficial structures appended to the cranium are frequently determined in the main by the shape of the fundamental cartilage to which they are attached." The application of this principle is well exhibited in the vasodentine dermal skeleton of Elasmobranchs in general, when there is no direct attachment or relationship to the muscles. But the illustration of the frontal spine is especially interesting. It is long when adapted to a long and strong rostrum (*Squaloraja* and *Myriacanthus*), short when adapted to a weak or reduced rostrum (*Ischyodus* and *Chimæra*); laterally compressed when on a laterally-compressed rostrum, vertically compressed when on a skull like that of *Squaloraja*.

EXPLANATION OF PLATE.

FIG. 1.—*Squaloraja polyspondyla*, Agass.: median rostral cartilage, probably of female, from above (*a*) and in transverse section at proximal end (*b*). *cr.* fragments of cranium; *l.* fibrochondral lamellæ. [British Museum.]

FIG. 2.—Ditto: transverse section of frontal spine, enlarged about 80 diameters, showing enclosed cells and blood-vessels, the upper edge representing the inner border resting against the soft cartilaginous axis.

FIG. 3.—*Chimæropsis paradoxa*, Zittel: cranium of female, about one-sixth nat. size; contour restored in dotted lines. [Palæontological Museum, Munich.]

FIG. 4.—*Squaloraja polyspondyla*, Agass.: frontal spine, inferior aspect, showing grooves for adductor muscles.

FIG. 5.—Ditto: transverse sections of spine, showing inner cavity and the bilaterally symmetrical arrangement of blood-vessels.

FIG. 6.—Ditto: dorsal aspect of head, restored after figures by Agassiz, W. Davies, and A. S. Woodward. *a*, *b*, calcified rings of "lateral line"; I, II*a*, II*c*, labial cartilages; R_I, median rostral cartilage; R_{II}, lateral ditto.

FIG. 7.—*Chimæra monstrosa*, Linn.: right half of anterior side of mouth and nasal opening, from below. The corner of the mouth and lip are raised to show arrangement of labial cartilages, and the arrow divides the labial complex into that of the upper and that of the lower lip.

FIG. 8.—Ditto: right side of head of male, a little from above, the skin removed as far as the eye, and displaying the lens (*l.*), iris (*ir.*), and the deep cutaneous or sclerotic fold (*sc.*) round the iris. The dotted surface indicates the rostral, cranial, labial, and mandibular cartilages. The tendon (*t.*) of the hinder attachment of the frontal spine connecting it with the cranial roof above the orbit is unshaded on the right side, and indicated by t_1 on the left side. The uppermost and hindermost fibres of the *adductor mandibularis* are attached to these tendons and to the broad inferior surface of the frontal spine itself (*f.s.*). The tendons of the *levator anguli oris* (*l.a.o.*) are attached on the upper anterior surface of the base of the spine. The tendons proceeding from the internasal cranial crest and the median rostrum itself (R_I) are the ligamental supports of the rostral sensory apparatus: the right lateral rostral cartilage (R_{II}) is seen in front of the nasal capsule (*n.*).

FIG. 9.—*Menaspis armata*, Ewald: left half of cranium and anterior portion of trunk, from above (after Jaekel), showing the probably male parietal horn-like (? chondrodermal) appendages (ph_I, ph_{II}, ph_{III}) and the true dentodermal lateral spine (*l.i.*) corresponding in form, attachment, and superficial ornamentation to the armature of the trunk, but differing in these and other macroscopical characters from the appendages *ph.*, probably chondrodermal calcifications like the frontal appendages of *Chimæra*, *Myriacanthus*, and *Squaloraja* (Figs. 6, 8, 11).

FIG. 10.—*Chimæra monstrosa*, Linn.: arrangement of "lateral line" in respect to the cranial, labial, and rostral cartilages below (*cf.* Fig. 6, *Squaloraja*).

FIG. 11.—*Myriacanthus granulatus*, Egert.: frontal spine showing lateral muscular grooves on proximal end. *cr.* cranium; R_I, median rostral prolongation.

FIG. 12.—*Chimæra monstrosa*, Linn.: longitudinal section (not quite median) of frontal spine, magnified. The soft cartilaginous (pro-fibrochondral) axis (*sa.*) is represented by the light shading; the calcified wall (*w.*) with the blood-vessels (*bl.v.*) is shaded darker. The black inferior surface of the spine serves for the attachment of a great part of the fibres of the *adductor mandibularis*; *l.a.o.* marks the attachment of the *levator anguli oris*. The median canal (*m.c.*), before subdividing into two lateral branches of blood-vessels, has a calcified surrounding wall, separating the soft axis into an anterior (sa_1) and a posterior (*sa.*) mass. The cutis (*cu.*) with the denticles (*d.*) is uncoloured.

II.—A Short Account of the Ammonites and their Allies, as Exhibited in the Cephalopod Gallery at the British Museum (Natural History).

By Arthur H. Foord, F.G.S.,
Of the Royal Dublin Society, Dublin.

THE great group of the Ammonites (using that term in its general acceptation) is distinguished from all other kinds of chambered shells of the Cephalopod type by the complicated foliations of the margins (*sutures*) of the partition walls or *septa* into which such shells are subdivided. Though typically coiled, much in the manner of the flat pond-snail, *Planorbis*, there are straight and variously curved Ammonites; but all have the common character of a highly foliated "suture-line."

The derivation of the Ammonites from the Goniatites has been clearly made out in certain groups by means of this suture-line, the development of which from its earliest stages of growth has furnished the key in such investigations.

The following sixteen families or sections of the Ammonites are the result of the most recent researches in this large and difficult group of fossils:—(1) Arcestidæ; (2) Tropitidæ; (3) Ceratitidæ; (4) Cladiscitidæ; (5) Pinacoceratidæ; (6) Phylloceratidæ; (7) Lytoceratidæ; (8) Ptychitidæ; (9) Amaltheidæ; (10) Arietidæ; (11) Ægoceratidæ; (12) Polymorphidæ; (13) Harpoceratidæ; (14) Pulchellidæ; (15) Haploceratidæ; (16) Stephanoceratidæ.

These sections will be found amply represented in the gallery set apart for their display.

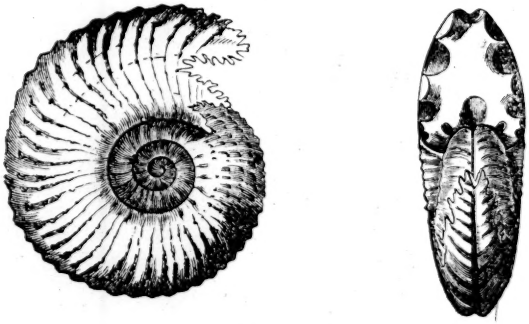
Omitting certain forms of doubtful relationship, to be subsequently dealt with, a brief account of the above groups may here be given. The first four families are found chiefly in the Permian rocks of Sicily and of India, and in the Triassic rocks of the Alps (Alpine Trias). Among the Arcestidæ may be noticed the singular Triassic genus *Arcestes*, with its deeply embracing whorls and contracted aperture. In the Ceratitidæ the well-known Muschelkalk species, *Ceratites nodosus*, with its peculiar suture-line (Fig. 2), and the richly ornamented shell of *Trachyceras Aon* (Fig. 1), are met with.

Three very peculiar shells also deserve notice. They are: *Choristoceras*, *Cochloceras*, and *Rhabdoceras*. In *Choristoceras*, the last whorl becomes separated from the preceding ones, in the manner of *Crioceras*. *Cochloceras* is turreted like a Gasteropod, and may

be compared with *Turrilites* in this respect. *Rhabdoceras* is straight, like *Baculites*. All are from the Alpine Trias.

The PINACOCERATIDÆ contain the large species known as *Pinacoceras Metternichi*, from the Keuper of Hallstadt, in Upper Austria. (Wall-case 12.)

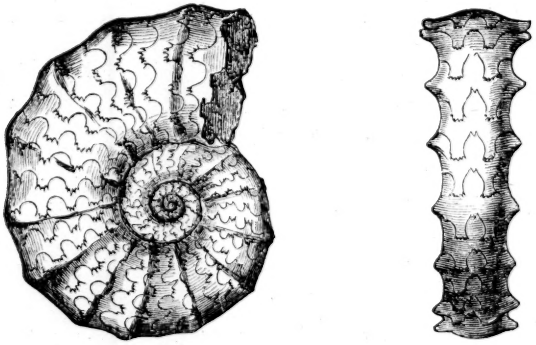
FIG. 1.



Trachyceras Aon, Münst. (Alpine Trias.)

The extreme delicacy of the ramifications of the sutures in this species excels that of any other Ammonite known. The leaf-like terminations of the sutures in the PHYLLOCERATIDÆ are the distinguishing feature in this group; they are well seen in the typical species *Phylloceras heterophyllum*, Fig. 3. (Wall-case 11.) This family began in the Trias, but it extended through the Jurassic into the Cretaceous.

FIG. 2.



Ceratites nodosus, De Haan. (Muschelkalk.)

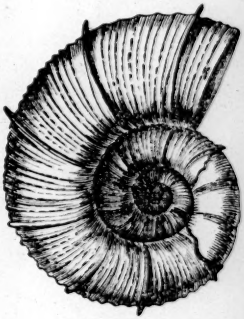
The suture-line is again the most important feature in the family next in order, viz. the LYTOCERATIDÆ, for it supplies the justification for connecting together an assemblage of genera differing widely in external shape. The family begins in the Trias, and is largely represented in the Jurassic and Cretaceous rocks. One of the most

beautiful species of this group is *Lytoceras fimbriatum*, whose regular, wavy lines running across the shell make it very attractive to the eye; the effect being heightened by the bold, sharp, transverse ridges encircling the shell at frequent intervals, representing the former "lips" of the shell, Fig. 4. (Wall-case 11.) In *Macroscaphites* (Wall-case 3, Table-case 61) the shell is for about four convolutions

FIG. 3.

Phylloceras heterophyllum, Sow. (Upper Lias.)

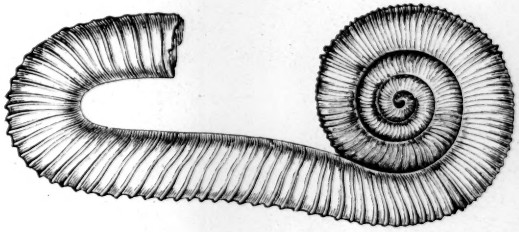
FIG. 4.



Lytoceras fimbriatum, Sow. (Middle Lias.)

or whorls exactly similar in shape to a *Lytoceras*, when it suddenly takes a direction tangential to the coiled part, and after pursuing a nearly straight course for a short distance it bends back in a hook-like termination (Fig. 5). In *Hamites* the shell is bent at both ends, the apical or smaller (initial) end being again bent: thus the shell has three curvatures. Owing to its slenderness the apical part

FIG. 5.



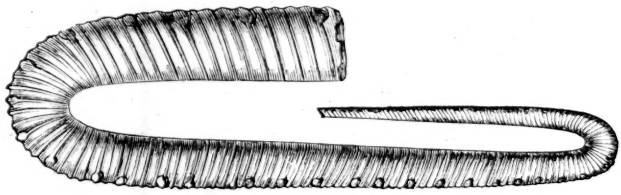
Macroscaphites Ivanii, d'Orb. (Lower Cretaceous.)

of the shell is rarely obtained (Fig. 6). (Table-case 60.) *Hamites* attains its greatest development in the Gault. In *Hamulina* and *Ptychoceras* (Neocomian and Gault) there is but one sharp bend in the shell, the straight limbs in *Ptychoceras* being actually in contact at, and in the region of, the aperture.

A still further departure from the typical form of the Cephalopod shell is encountered in the singular genus *Turrilites*, which takes

the form of a Gasteropod shell (Fig. 7). The mouth or aperture is, however, turned towards the left-hand side, or, in other words, the shell is "sinistral." *Turrilites* is found exclusively in Cretaceous rocks. (Wall-case 3, Table-case 60.) *Helicoceras* is coiled like *Turrilites*, but the whorls are disconnected. In *Heteroceras* the last

Fig. 6.

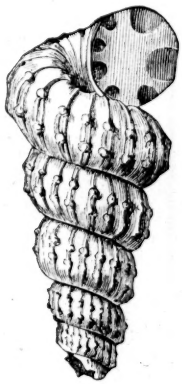


Hamites elegans, d'Orb. (Cretaceous.)

whorl is detached (Fig. 8). Both are Cretaceous genera. (Table-case 57.) In *Baculites* (Cretaceous) the shell is perfectly straight, except in the earliest or embryonic stage of its development, in which it is coiled. It occurs in vast numbers in the Danian (Upper Continental Chalk) of the North of France, whence the name *Baculite* Limestone given to those beds (Fig. 9). (Wall-case 3, Table-case 60.)

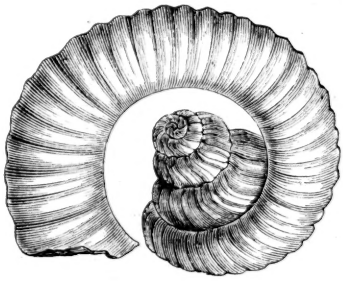
The next group, Ptychitidæ, consists for the most part of Triassic genera, but its earliest representatives come from the

Fig. 7.



Turrilites catenatus, d'Orb. (Gault.)

Fig. 8.



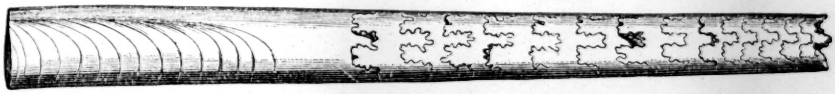
Heteroceras Emerici, d'Orb. (Cretaceous.)

Permian rocks of Sicily. *Ptychites* and *Gymnites* from the Alpine Trias are among the best known genera. *Daraelites* of the Permian of Sicily is specially interesting from the fact that its sutural characters resemble those of some of the Goniatites, and taking the Ptychitidæ as a whole it is considered that they present a

gradational series connecting the Goniatites with the Ammonites. (Table-case 69.)

The principal feature observable in the AMALTHEIDÆ is the *keel* or projecting edge of the outer border (periphery) of the shell, which is prolonged beyond the margin of the aperture in the form of a long narrow process. In *Amaltheus margaritatus* (Middle Lias) the keel is prominent and beautifully sculptured, resembling the

FIG. 9.

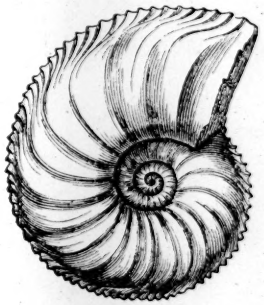


Baculites anceps, Lam. (Upper Cretaceous.)

strands of a miniature rope. *Cardioceras cordatum* (Oxford Clay) is one of the most highly ornamented of Ammonites, having a series of numerous sharp ribs upon the sides of the shell, which, in passing over the periphery, form a series of fine crenulations (Fig. 10). *Schloenbachia varians* (Lower Chalk) has strong and knotted ribs. (Wall-cases 5, 9, 11; Table-cases 62–69.)

The family of the ARIETIDÆ embraces a large number of Ammonites which at first sight appear to be only remotely related, nevertheless a careful study of their development has led to their

FIG. 10.



Cardioceras cordatum, Sow. (Oxford Clay.)

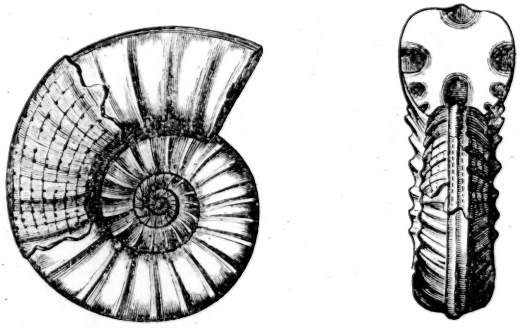
being grouped together. Among the most familiar members of this large group are the following, viz.: *Psiloceras planorbe*, which gives its name to the "zone of *Ammonites planorbis*" of the Lower Lias, and at the same time marks the first occurrence of Ammonites in British rocks; *Arietites Bucklandi* (*A. Bucklandi* zone); *Arietites obtusus*, Fig. 11 (*A. obtusus* zone); and *Oxynoticeras oxynotum* (*A. oxynotus* zone).

The shells in this group are flattened in form, and the whorls usually only slightly embracing, and generally numerous (see *Psiloceras planorbe*, e.g.). *Oxynoticeras oxynotum* is remarkable for the

extremely attenuated and trenchant form of the adult shell. In this species the whorls are deeply embracing, so that very little is seen of the inner volutions. (Table-case 68, Wall-case 12.)

The ÆGOCERATIDÆ are restricted to one genus, *Ægoceras*, of the Lias. *Ægoceras capricornus*, Fig. 12 (*A. capricornus* zone of the

FIG. 11.

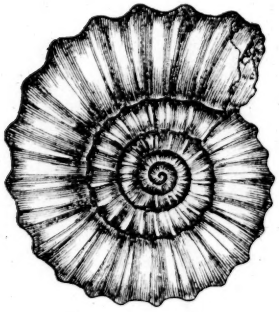


Arietites obtusus, Sow. (Lower Lias.)

Lower Lias), *Æ. Davœi* (Fig. 13), and *Æ. armatum* of the Lower Lias are some of the most characteristic species. The last-named species is conspicuous for the long spiny processes projecting from the sides of the shell. (Wall-case 12.)

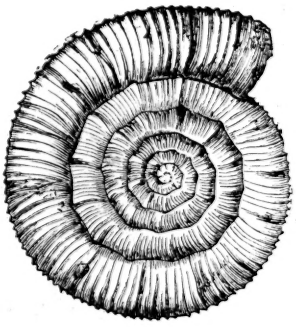
The family POLYMORPHIDÆ has been constituted to contain certain genera which have been separated from the ÆGOCERATIDÆ on the

FIG. 12.



Ægoceras capricornus, Schloth. (Lower Lias.)

FIG. 13.



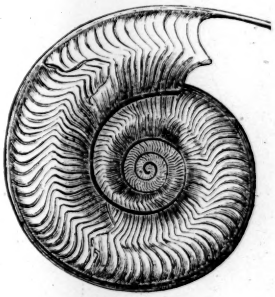
Ægoceras Davœi, Sow. (Lower Lias.)

one hand and from the HARPOCERATIDÆ on the other. It is notable for the variations undergone by the shell in passing from the young to the adult stage of growth. *Liparoceras Bechei* (Middle Lias) is a well-known species with a highly ornate shell. *Hammatoceras Sowerbyi* (Lower Oolite) has a keeled margin in the young shell

which it loses in the adult, while the umbilicus, at first narrow, becomes ultimately wide. (Wall-case 10.)

The HARPOCERATIDÆ are derived from the ARIETIDÆ. The oldest forms begin in the Middle Lias, and they extend into the Inferior Oolite. The shells are flattened and keeled, and have falciform or sickle-shaped ribs, or striæ. *Hildoceras bifrons*, from the Upper Lias of Whitby, shows this kind of ornamentation very distinctly.

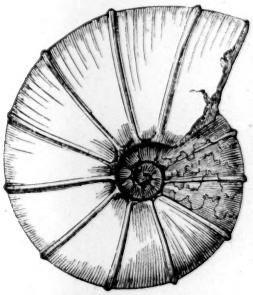
FIG. 14.



Grammoceras serpentinus, Schloth. (Upper Lias.)

Leioceras opalinum (Lower Lias) is another characteristic species, the aperture with ear-shaped lateral processes. *Grammoceras serpentinus* (Fig. 14) characterizes the "*Serpentinus* zone," or Jet Rock, which has yielded some of the finest and best preserved Ammonites of the Yorkshire Lias. Of Inferior Oolite species *Ludwigia Murchisonæ*, Sow., and *Oppelia subradiata*, Sow., may be mentioned. (Wall-case 10.)

FIG. 15.



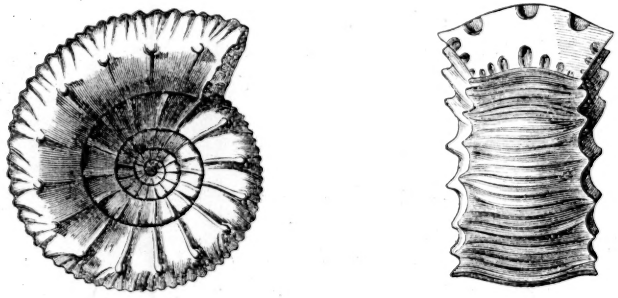
Desmoceras ligatum, d'Orb. (Neocomian.)

The PULCHELLIDÆ (Cretaceous) are remarkable for the simplicity of their suture-line, some resembling Goniatites, others Ceratites, in this respect. They are considered to be true Ammonites, descendants of the Jurassic HARPOCERATIDÆ, but in a state of degeneracy. *Pulchellia compressissima* (Lower Cretaceous) and *Neolobites Vibrayeanus*

(Upper Cretaceous) may be cited as examples of this small group. (Table-cases 63, 64.)

The HAPLOCERATIDÆ, ranging from the Inferior Oolite to the Middle Chalk, differ in many respects from the HARPOCERATIDÆ, from which they branch off. The shell is generally thick, sometimes remarkably so, as in *Pachydiscus peramplus* of the Middle Chalk; there are also periodic constrictions or grooves upon the

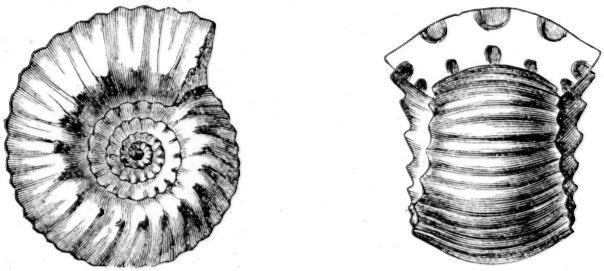
FIG. 16.



Stephanoceras Blagdeni, Sow. (Inferior Oolite.)

surface, which gave rise to the old group-name *Ligati*. Finally, the contour of the edge or periphery of the shell is uninterrupted, there being no keel such as is met with in the HARPOCERATIDÆ. There is an aptychus in a few forms. Of the flatter kinds of shells of the present family, *Desmoceras ligatum* (Fig. 15) of the Neocomian and *Desmoceras planulatum* of the Gault may be referred to as examples. (Table-case 64.)

FIG. 17.



Stephanoceras coronatum, d'Orb. (Callovian.)

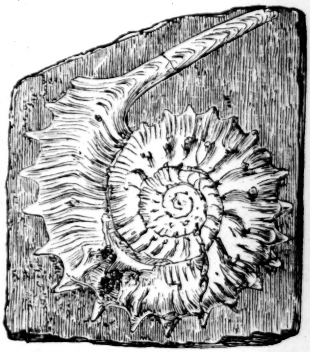
The last section to be described is that of the STEPHANOCERATIDÆ, an extensive and varied group of shells which are characterized in many cases by the symmetrical and beautiful ribbing with which they are ornamented. A few examples will serve as illustrations, viz. *Stephanoceras Blagdeni* (Fig. 16), Inferior Oolite, *Stephanoceras coronatum* (Fig. 17) and *Cosmoceras Jason* (Fig. 18), of the Callovian

or Oxford Clay, and *Hoplites radiatus* (Fig. 19), of the Neocomian. (Wall-cases 5, 9, 10; Table-cases 62–68.)

Another characteristic shell of this group is the *Acanthoceras Rhotomagense* of the Lower Chalk. (Table-case 62.)

A small group of forms still remains to be considered whose structure (external and internal) has led to their being regarded as

FIG. 18.



Cosmoceras Jason, Rein. (Callovian.)

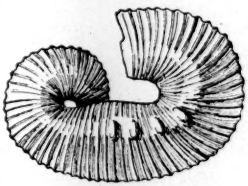
FIG. 19.

Hoplites radiatus, Brug. (Neocomian.)

offshoots from the STEPHANOCERATIDÆ. They may be divided into two sections—the first, consisting of shells partly uncoiled; the second, in which the shells are completely coiled, with deeply embracing whorls.

Section I.—The form of *Scaphites* immediately recalls that of *Macroscaphites*, but it differs in several particulars: it is much more closely coiled, that is, the inner coils of the shell are not seen,

FIG. 20.

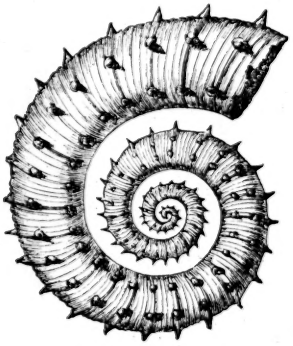


Scaphites Hugardianus, d'Orb. (Cretaceous.)

being covered up by the succeeding ones; and further, the uncoiled part is much shorter and its outline more rounded, while it bends over so as to almost reach the coiled part. *Scaphites* is abundant in the Middle and Upper Cretaceous. (Table-case 61.) *Crioceras* has the form and curvature of an Ammonite, but the whorls are not in contact (Fig. 21). It was formerly supposed that this genus was wrongly

founded upon broken shells of *Ancyloceras* (*q. v.*); but the discovery of the aperture has dispelled this error. There is no doubt, however, that *Toxoceras* is nothing more than a fragment of *Crioceras*. *Ancyloceras* begins like *Crioceras*, but at the last whorl the shell is straightened out at a tangent to the coiled part, and after attaining

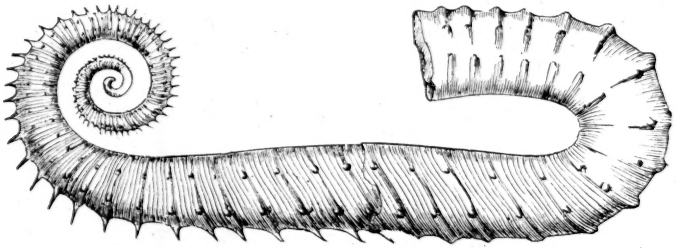
Fig. 21.



Crioceras Emerici, Léveillé. (Neocomian.)

a considerable length in a straight course it bends over abruptly in the direction of the coiled part, as in *Scaphites*. *Crioceras* and *Ancyloceras* are variously and elegantly ornamented with ribbing, spines, and tubercles. *Crioceras* extends from the Neocomian to the Upper Greensand; *Ancyloceras* from the Inferior Oolite to the Chalk.

Fig. 22.



Ancyloceras Matheronianum, d'Orb. (Neocomian.)

Section II.—This section includes Ammonites of flat, disc-like form, with *Ceratites*-like sutures and deeply embracing whorls. *Sphenodiscus* and *Buchiceras* (Upper Cretaceous) are characteristic genera. *Placenticeras* (Cretaceous) includes such species as *P. Largillertianum* and *P. Orbignyanum*.

An hour spent in this gallery will well repay the student interested in the study of the fossil Cephalopoda.

III.—A Description of *Ceramurus macrocephalus*, a small Fossil Fish from the Purbeck Beds of Wiltshire.

By Arthur Smith Woodward, F.L.S., F.G.S.,
Of the British Museum (Natural History).

SINCE the publication of some notes on the English Purbeckian Fishes a few months ago,[1] the writer has been favoured by the Rev. P. B. Brodie, M.A., F.G.S., with the opportunity of re-investigating and comparing the original specimen of the small problematical fish *Ceramurus macrocephalus*, briefly described by Egerton[2] from the Purbeck Beds of the Vale of Wardour. Most of the early descriptions of fossil fishes are inadequate for present needs; and no genus and species could be less satisfactorily characterized than that just referred to. A new attempt to elucidate the fossil, in the light of modern knowledge, is thus very desirable, more especially as no other specimens of the same fish have hitherto been recognized.

Egerton's original description, accompanying Brodie's figure, is merely a brief note. He remarks that this little fish "presents the nearest affinity to the remarkable genus *Megalurus*, but differs in its slender form and the large proportional size of the head. The vertebræ seem to be fewer in number, and of smaller diameter. The most characteristic feature is the tail, which is strengthened above and below by broad, elongated, fulcral scales. This interesting specimen may be designated by the name of *Ceramurus*, or tile-tail, from the character of the fulcral scales supporting the lobes of the caudal fin. The species may be called *macrocephalus*." Such is the complete quotation, and no further particulars as to the genus and species have hitherto been published.

The fish in question is preserved in counterpart, but the head and caudal fin are imperfect, while a vein of calcite crosses it obliquely at the hinder end of the abdominal region. There is also some displacement at the back of the branchial region. The length of the head with opercular apparatus must have been about twice as great as the maximum depth of the trunk, while it would probably be contained four times in the total length of the fish. No feature worthy of note can be observed in the fragments of the head. The vertebral centra are delicate rings, which appear to have been disposed in a spaced series so that in their crushed condition they are exposed mostly in end-view. It is not possible to count them. The neural arches in the abdominal region are much shorter than their appended spines, which are loosely apposed apparently by a forked base. The ribs are short, and especially delicate. The neural and hæmal spines in the caudal region are fused with their respective arches, and these also probably with the vertebral centra. The axis is much turned upwards at the base of the caudal fin, and the hæmal spines are thickened as usual. There are no traces of

[1] "A Contribution to Knowledge of the Fossil Fish Fauna of the English Purbeck Beds," Geol. Mag., Dec. IV, Vol. II, p. 370 (April 1895).

[2] In P. B. Brodie's "Fossil Insects," p. 17, pl. i, fig. 2 (1845).

intermuscular bones. The fins consist of long slender rays, with distant articulations, and apparently never forked more than once at the distal end. Each is fringed by three or four very long and slender fulcra, which are conspicuous by their enamelled surface. The slender pectoral arch of one side is displaced backwards, and the imperfect pectoral fins, with the characteristic fulcra, are shown. One of the hour-glass-shaped pelvic fin-supports is exhibited, and some of the delicate pelvic fin-rays adpressed to the trunk reach as far as the origin of the anal fin. The dorsal fin is short-based, arising near the middle of the back and opposite to the pelvic pair. Nine supports, of which the anterior ones are stouter than the rest and somewhat winged, can be counted in front of the disturbing vein of calcite; and the long dorsal rays are pressed down upon the back so that their distal ends appear behind this vein. The anal fin arises behind the posterior end of the dorsal, and comprises about eight rays, which when adpressed reach nearly to the base of the caudal fin. The latter fin is imperfect and distorted, and it is impossible to determine whether or not it was forked. Delicate scales may have covered the trunk, but there is no clear evidence of them. Robust ganoid ridge-scales, however, are observable on both borders in the hinder half of the caudal region; and those of the dorsal border are shown to be remarkably acuminate, the apex of each scale being especially produced into a long point at the base of the upper caudal lobe.

In short, so far as can be determined from this unique specimen, *Ceramurus* does not exhibit any special feature of resemblance to *Megalurus*. The fins bear large fulcra, while those of *Megalurus* are non-fulcrated; the form of the caudal fin is unknown; the dorsal fin is remarkably short; the vertebral centra are merely spaced rings. On the whole, the fish appears to the present writer to be most closely related to *Pholidophorus*, and it will probably prove to have a forked tail. The axial skeleton of the trunk, the fins, and the caudal ridge-scales are especially suggestive of *Pholidophorus*; but *Ceramurus* differs in the large size and fewness of the slender fin-fulcra, in the unusual development and serried arrangement of the dorsal ridge-scales of the tail, and in the *apparent* absence of scales on the flanks. The fish may, therefore, be provisionally assigned to the Pholidophoridæ, under the generic and specific name which Egerton proposed for it.

IV.—Notes on "The Great Ice Age" in Relation to the Question of Submergence.

By Dugald Bell, F.G.S.

(*Continued from p.* 355.)

V. Changes of Level in Relation to Climate.

LEAVING those local matters, there is a point of some general interest, suggested by several passages of Dr. Geikie's work, which we should like briefly to notice before laying it aside. It is in regard to those repeated depressions and re-elevations of the

land which he still favours in connection with the Glacial epoch. Dr. Geikie's latest "scheme" of that epoch seems to include at least *five* Glacial and *four* inter-Glacial periods, accompanied by submergences and re-elevations to the extent of between 500 and 600 feet—the maximum being for the present restricted to that amount.[1] Frankly, we confess ourselves unable to see the proofs for so many Glacial and inter-Glacial periods, of which, if they did occur, it would apparently be impossible—on the author's own premises as to glacial erosion—now to discover any traces. Apart from this, we might remark on the inherent improbability of such extensive oscillations of the earth's crust having happened in recent geological times, without leaving more distinct evidence of themselves than the very scanty and doubtful deposits which we have been considering.

Let us look, however, for a little at such alleged movements in one aspect only—their relation to glacial conditions. We think it may be taken as a certain *datum*, to begin with, that in itself a high elevation of the land tends to bring about colder conditions; and on the other hand, a depression or submergence of the land is distinctly favourable to milder conditions of climate. In this country, for example, an elevation of a few hundred feet would bring a considerable extent of our mountainous regions within the limits of perpetual snow. It would also ward off to a greater distance the warmer currents of the sea, and in these and other more indirect ways it would obviously lower the general temperature of the country. On the other hand, a submergence of a few hundred feet, by lowering and diminishing the high lands, and by admitting more freely the ocean currents—the great distributors of heat and equalizers of temperature—would certainly go far to bring about milder and more genial climatic conditions. So that, as Lord Kelvin has pointed out, with a far more moderate submergence than many are in the habit of imagining, in the northern hemisphere, there would in all likelihood be no snow or ice at all till some point far up within the Arctic circle, and perhaps not much even there.[2]

Sometimes impossible currents are invoked from unknown regions, to perform tasks that are plainly beyond them. So long as the earth has revolved on its present axis, and the great continents of its surface have occupied their present position, so long, it would seem, must the general system of aerial and ocean currents have been the same. Our belief in the general similarity of conditions in these respects during the Glacial period, and at present, is confirmed by the fact—admitted by Dr. Geikie—that alike in Europe, Asia, and America, the areas of maximum precipitation during the Glacial period corresponded to the areas of maximum precipitation still. "The former distribution of snow and ice was in strict accord with existing conditions: . . . . there can be no doubt that the conditions

[1] See "Great Ice Age," pp. 323–325, 421 and 422. Also "Fragments of Earth Lore," pp. 319–321.

[2] "On Geological Climate," Trans. Geol. Soc. Glasgow, vol. v.

of Glacial times bore an intimate relation to those that now obtain" ("Great Ice Age," p. 777). We cannot see, then, how it could possibly be otherwise than that elevation and colder conditions, submergence and warmer conditions, must have gone together. This cardinal principle, we submit, should be borne in mind in the construction of any scheme of events for the Glacial period.

Now, from this point of view, we can make nothing of Dr. Geikie's "succession of events" during that period; the physical changes and climatal conditions set forth seem to be utterly disconnected, and indeed at variance with each other. Thus, to take a few instances, we read—

"The climate certainly must have become cold and ungenial as the depression continued" (p. 312).

"Scotland submerged . . . . The climate had deteriorated" (*ibid.*).

"The land gained on the sea until the latter had retreated considerably beyond its present limits. The climate at the same time became more genial" (p. 313).

"Submergence next ensued, the climate at the same time passing from temperate to Arctic" (p. 323).

"Re-elevation of the land, or retreat of the sea, and a gradual amelioration of climate" (p. 325).

"Submergence once more ensued . . . . and the climate at the same time became colder" (*ibid.*).

From these and other passages which might be quoted it would seem that the author regards elevation as somehow productive of more genial conditions, and submergence as associated with colder and more severe conditions of climate.

We hold the opposite view so strongly that when shells of distinctly Arctic species are found (as in some instances they have been) at a considerable elevation, that very circumstance, to our mind, casts "ominous conjecture" on their being really in place.

We may remark, in closing, that these numerous distinct Glacial periods, accompanied by repeated depressions and re-elevations, are not borne out by the observations of geologists in other countries. Unless cause be shown to the contrary, the probability surely is that the conditions prevailing here during the Ice Age were similar to those prevailing in other parts of the Northern hemisphere. We have already quoted Dr. Geikie to the effect that "no evidence of marine action has been detected in the formation of the stony clays" which cover "the low grounds of Northern Europe" ("Great Ice Age," pp. 432–3). "Nowhere do German geologists find any evidence of marine action"—that is, in the Boulder-clay. The overlying so-called "inter-Glacial" deposits within the Baltic area, as a rule only attain a very moderate elevation (pp. 448–50). In Sweden, two Boulder-clays are recognized, a lower and an upper; but Torneböhm says they have "both been formed in the same way, and are true *moraines de fond*, and that in the interval between them, marked by a partial retreat of the ice, "the land was not submerged." In short, "the majority of geologists on the Continent believe that there

have been only two Glacial epochs, separated by an inter-Glacial epoch of more genial conditions" (pp. 445–6).

This corresponds very well with the results arrived at generally by the American geologists: they recognize three stages—the *early* Glacial epoch, characterized by ice-accumulation to its maximum extent; the *middle* Glacial epoch, or that of the first retreat of the ice; and the *later* Glacial epoch, or that of the final retreat (Dana; see also Chamberlin, in "Great Ice Age," p. 773).

But some prefer to regard the whole as really *one* epoch, though varying from time to time in intensity and local extent.

While not unaware of local difficulties, we respectfully submit that Dr. Geikie's complicated system of so many Glacial and inter-Glacial periods, and so many submergences and re-emergences, from 500 or 600 feet downwards—with their varying and apparently inscrutable effects upon climate—tends on the whole to increase these difficulties, and should therefore be "reformed altogether."

V.—A Note on the Torbay Raised Beaches and on the Detached Blocks trawled in the English Channel.

By A. R. Hunt, M.A.

IN Professor Prestwich's important paper on the Raised Beaches of the South of England[1] the following passage occurs: "In Torbay there are small portions of a Raised Beach near Paignton...." As on the strength of this statement the line of Raised Beaches is carried in the map round the extreme present limits of Torbay, and the hitherto universally accepted doctrine, that Raised Beaches do not occur in the softer parts of the coast-line, is thus controverted, the assertion is one of considerable importance.

In my own paper on the Raised Beaches I wrote, in 1888[2]—"The stage of the erosion indicated by the Northern Torbay Raised Beaches is that when the east and west coast-line had not passed the line of Torbay, and Torbay itself was but in an early stage of formation." A Raised Beach at Paignton would subvert this conclusion, and the numerous facts on which it was based.

Desirous as I necessarily was to investigate the reputed Paignton beach, Professor Prestwich in the most generous way offered me every facility. The authorities relied on were Messrs. Pengelly and Ussher. As it happened, Messrs. Pengelly and Ussher, and myself, had all written independent papers on the few hundred yards of coast in question; so there was no lack of literature to fall back on.

My first impression was that Mr. Pengelly might have described as a beach an eroded bed of conglomerate very like a Raised Beach in the sandstone of Roundham Head, which bed he used to point to as an instance of contemporaneous erosion of Triassic age, and possibly a Raised Beach, though one in no way connected with the Quaternary beaches. This deposit, however, does not seem to be noticed in any of his papers. Referring the question to Mr. Ussher,

[1] Quart. Journ. Geol. Soc., vol. xlviii, p. 279.
[2] Trans. Devon Assoc., vol. xx, p. 250.

he reminded me of a gravel bed between Paignton and Torquay, described in his paper mentioned above, wherein Mr. Ussher writes—"We have in the alluvial deposits of the Goodrington and Paignton flats, and in the blown sands extending from Roundham Head to the north part of Preston Sands, and in the present sea-beaches, the latest evidences of Pleistocene deposition. Of these three phenomena the gravels near the gasworks are probably the oldest. . . . . All these events transpired within that most recent part of the Pleistocene period which succeeded the formation and elevation of the old beaches of Hope's Nose and other places."[1] We see clearly that Mr. Ussher here knows of no "old beach" at Paignton, as, his subject being "The Geology of Paignton," he goes to Hope's Nose for an example of such deposits. Mr. Pengelly, writing of precisely the same locality, observes—"A glance at the existing beach at the foot of the cliff, a study of the Raised Beaches *almost in sight*," etc.[2] (italics mine). The Raised Beaches "almost in sight" are again those at Hope's Nose and Brixham; the one obscured from view by Daddy Hole Point, the other nearly five miles distant across the bay.

Mr. Pengelly clearly, though writing of Paignton Quaternary Geology, knew of no Raised Beach there. It may, I think, be accepted as a fact that no Raised Beach at Paignton has been known to any local geologist. But as both Mr. Pengelly and Mr. Ussher spoke of Raised Beaches in connection with the geology of Paignton, a reader might easily remain under the impression that Raised Beaches occurred in the immediate neighbourhood. "Beaches almost in sight" might very well be round the next headland instead of the nearest being three miles distant.

A Raised Beach at Paignton would snap a very pretty chain, or set of chains, of evidence, reconstructing the ancient coast-line. There is an immense amount of work still awaiting the right man in the sands and pebbles of the ancient beaches. Never was I more struck by geological evidence than I was by two pebbles at Brixham—one absolutely indistinguishable in form from the spheroidal chert of Chesil; the other a characteristic igneous rock from the Teignmouth conglomerates, found, I believe, nowhere else. These stones must have travelled across the mouth of Torbay, about 20 feet or so above the level of present high-water. Such a fact signifies volumes! By no possibility could these pebbles have travelled round such a bay as Torbay is now. These stones alone suffice to forbid the possibility of a Raised Beach at Paignton, at any rate one contemporaneous with the rest.

In Professor Prestwich's paper referred to, the author, while mentioning my work in the kindest manner, cites me as an authority in favour of the view that blocks trawled in the English Channel were ice-borne, *e.g.*, "Mr. Hunt dismisses the hypothesis of adjacent land-ice, owing to the absence of similar blocks between Dartmoor and the sea, and concludes that they were brought there by floating

[1] Trans. Devon Assoc., vol. x, p. 203.
[2] *Loc. cit.*, p. 200.

ice."[1] This is not quite so. I wrote as follows: "If, on the other hand, they [the blocks] were brought by floating ice from distant regions, it remains to be explained why they should be found collected together in a limited area of the English Channel." I meant that no such explanation was forthcoming; and continued subsequently—"The stone itself may be considered *primâ facie* evidence that the large detached stones in the sea off Salcombe are really granite, and that the ground on which they lie is granite too."[2] This was in 1879. Many varieties have occurred in addition to granite since then. My very last words on these stones, in 1889, were—"However, it is clearly impossible to prove that some of them may not have been ice-borne. Let those who maintain that theory show cause for their belief."[3] The evidence is strangely conflicting. About seven years ago I was staggered by a suggestion which reached me from an influential quarter that it might be doubtful whether there was anything further to be written on the subject of the detached blocks trawled in the English Channel. As a matter of fact, the necessary work is no more than commenced; and there is no prospect of it ever being resumed.[4] Let me dwell for a moment on one single point—Let us assume that the crystalline blocks are ice-borne: we are at once confronted with the fact that they occur in an area of sands and gravels partly derived from crystalline rocks, which sands and gravels are certainly not ice-borne. In such an inquiry it is not safe to take anything for granted. It seemed safe to assume, as was assumed, that the Channel granites were connected with Dartmoor; whereas they have proved themselves perfectly distinct. So, before taking for granted a connection between the Channel blocks and the Sussex boulders, it will be necessary to compare them in detail, and minutely. It will also be necessary to do the same by the Channel crystalline gravels, to ascertain whether they are related to England or to France; to both, or to neither. The coming man should have his steam yacht, enthusiasm, patience, the acuteness of a Sherlock Holmes, be a good practical micro-petrologist, and prepared to follow where the clue leads instead of where he thinks it ought to lead. Before the days of the microscope and steam, analogous work was done by such men as Mr. Godwin-Austen, and it is to their successors we must look in the future. To any such worker Professor Prestwich's paper must prove of the greatest value, suggesting as it does innumerable subjects for detailed research, as well as problems to be solved and theories to be tested.

[1] Quart. Journ. Geol. Soc., vol. xlviii, p. 297.

[2] Trans. Devon Assoc., vol. xi, p. 316.

[3] *Ibid.*, vol. xxi, p. 485.

[4] The difficulty lies in interesting the fishermen sufficiently to preserve hand specimens, and to take notes as to bearings. I was fortunate enough to interest a most intelligent and trustworthy crew, on whom I could place all reliance, and whose zeal was stimulated by half-a-crown for each large block, of which a fragment was preserved and whose position was ascertained. Their vessel changed hands long since, and her crew was dispersed. Thanks to my friend Professor Hughes all their carefully collected specimens are preserved in the Woodwardian Museum.

In conclusion, I may refer to a paper read by my esteemed colleague, Mr. D. Pidgeon, to the Geological Society in 1890, in which, on the evidence of the shells and beach materials sent to him, he disputed the genuineness of the Raised Beaches of Hope's Nose and the Thatcher Rock.[1] Mr. Pidgeon, with his accustomed keen eye for important detail, has pointed out certain very significant facts previously unnoticed, and still unexplained; but the proof of the genuineness of the beaches lies in evidence quite independent of the minute structure of the beach-material, organic or inorganic. Had my friend been able to visit the beaches, I feel assured he would never have questioned their genuineness; and think it highly probable he would have found some very satisfactory explanation for the angularity of certain of the inorganic, and for the fractured state of certain of the organic, components of the deposits in question. During the many years over which my own investigations extended, I never gave these two points a thought; and since Mr. Pidgeon's paper was published have not set foot on the Thatcher Rock.

VI.—The Viscous Flow of Glacier-Ice.

By R. M. Deeley, F.G.S.

ALTHOUGH, ever since the classical researches of J. D. Forbes on the phenomena presented by the Swiss glaciers were published, it has been recognized that glacier-ice behaves like a viscous liquid, and flows from high to low levels much in the same way as does a river of water, it is apparent that many who have interested themselves in the subject of glacier-flow, and have written rather dogmatically on the subject, have not clearly realized the nature of the phenomenon. Very contradictory and erroneous conclusions have consequently been arrived at, with the result that it is now somewhat difficult for those who have not made a special study of the subject to distinguish what may be fairly regarded as ascertained fact from that which is purely matter of opinion.

I will, therefore, venture to state as clearly as possible the laws of viscous flow (as I understand them) as deduced from experiment, and then inquire to what extent the motion of a glacier approximates to the conditions of such flow.

Our knowledge of the subject is by no means due to recent discovery. The viscous flow of liquids—and glacier-ice behaves as a very viscous liquid—was worked out by Poiseuille and Coulomb. Later, we have Helmholtz, O. E. Meyer, Graham, Clerk Maxwell, and Osborne Reynolds. The discoveries of these workers are quite sufficient to enable us to work out the more important phenomena presented by glacier-flow from first principles. Indeed, had sound physical theory been adhered to by all writers on the subject of glacier erosion and transport, the mistakes so many have fallen into might have been avoided. Fortunately such investigators as Prof. James Geikie have been able to keep the balance of opinion from inclining in the wrong direction.

[1] Quart. Journ. Geol. Soc., vol. xlvi, p. 438.

In treating of viscosity we are at the outset met by a verbal difficulty. Viscosity and plasticity have both been used to denote the same physical property. Some writers speak of ice and pitch as being plastic as well as viscous. It is better, however, to follow Maxwell,[1] who defines a viscous body as one which undergoes continuous change of form under stresses, however small. All viscous substances are on this view true liquids. A plastic substance, on the other hand, only undergoes continuous change of form when the stress exceeds a certain value. When the stress required to cause continuous distortion is small, the substance is called a *soft solid.* Until this limiting stress is reached the substance is elastic, and the stress at which what is known as perfect elasticity ceases to be obtained, and the substance undergoes permanent deformation, is called the *limit of perfect elasticity.*

We must also recognize that there are *hard solids.* In them, when the stress exceeds the limit of perfect elasticity, the substance begins to yield more or less steadily as the stress increases. In some cases after this limit is reached the solid suffers a sudden permanent elongation. It afterwards regains its strength, and then only yields further with increasing stress.

The point at which the material gives way is called the *yield point,* and as it coincides very nearly with the limit of perfect elasticity, and is easily detected, it is now always noted by practical engineers. But the distortion of a *hard solid* is not produced under the conditions which give rise to viscous flow. Indeed, the action of the stress often appears to produce an allotropic change in the material. The whole subject is a most difficult one, and has by no means been completely worked out. There is no real boundary separating a hard from a soft solid. The soft solid under a sufficiently great stress yields much as a viscous fluid does; whilst the hard solid often fractures, and definite shear planes or faults are formed.

The difference between plasticity and viscosity is one of fundamental importance to the engineer, for as long as the stress put upon a foundation does not exceed the *yield point* the structure raised upon it is permanently stable. It is quite otherwise with a viscous material. No possible foundation can be stable upon such a substance unless it be made to float like a ship upon water; for, however large the area upon which the stress acts, the foundation will yield continuously.

With increase of temperature the yield point and limit of perfect elasticity grow smaller and smaller in many instances; and a soft solid or plastic material may, with rise of temperature, become a viscous liquid.

By many the difference between the plastic and viscous condition is not properly appreciated. We have our softer rocks spoken of as though they were viscous, and various theories of soil-cap motion propounded to explain phenomena resulting from other agencies.

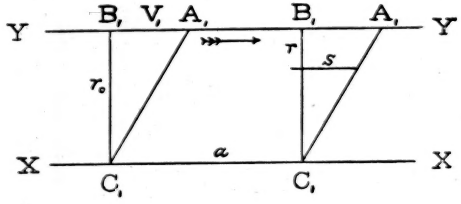
[1] "Theory of Heat," 1894 edition, p. 303.

When saturated with water many sands, clays, and loams do become very plastic, and flow almost like viscous fluids. Excellent instances of such flow may be seen at the base of the Cromer cliffs.

We must regard the solid crust of our earth as being hard, truly plastic, or plastic under great pressure, not viscous. Except as the result of denudation, or from the action of internal forces, which occasionally bring the stresses above the limit of perfect elasticity, our mountain ranges are stable and not tending to level up as they would do if composed of even a much more viscous substance than pitch. To quote Maxwell,[1] "A tallow candle is much softer than a stick of sealing-wax; but if the candle and the stick of sealing-wax are laid horizontally between two supports the sealing-wax will in a few weeks in summer bend with its own weight, while the candle remains straight. The candle is, therefore, a soft solid, and the sealing-wax a very viscous liquid."

The term viscosity, however, has been used to indicate a property of solids of quite another kind. That it should have been used in such a way is unfortunate, for the property known as *solid viscosity* is quite different from that of a liquid. To make this quite clear the phenomenon presented by a solid substance under the action of a stress will be considered before treating in detail the conditions of liquid flow.

FIG. 1.



The space between two planes, Fig. 1, one of which YY is free and the other XX fixed, we will regard as being occupied by a solid substance. Under a given stress, acting along the plane YY in the direction of the arrow, the solid undergoes an elastic shear equal, we will say, to the displacement of B_1 to A_1. But, the stress remaining constant, it will be found that with the lapse of time this displacement slowly increases in amount, especially if the solid be set in vibration, and only reaches a maximum after a very considerable interval has elapsed. On removing the stress the plane returns at once to almost its original position. But the last traces of distortion only disappear after the lapse of many hours. Indeed, in many instances the original configuration is never regained, the behaviour of the material as it were depending upon its previous history.

We will now consider the conditions of flow of a thin stratum of a viscous liquid placed between the planes XX and YY, the

[1] "Theory of Heat," 1894 edition, p. 303.

upper one of which is moving at a uniform speed in the direction of the arrow. Observation shows that in such a case, owing to the resistance offered by the liquid to shear, the stress is transmitted from layer to layer of the liquid, and each portion of the fluid moves at a velocity which increases uniformly as we recede from XX and approach YY. Of course the motion of the fluid is regarded as having reached a steady state; inertia-effects consequently do not show themselves. Hence the particles originally forming the lines $B_1 C_1$ in the figure after a certain interval of time have positions on the lines $A_1 C_1$. As these lines are on the same base and between the same parallels, the inclosed space retains its original area. Distortion only has been produced, each horizontal layer having moved over the one below it. It must be clearly understood that to produce these conditions of motion the stress must not act with equal force on each particle of the fluid, but solely along the plane YY, and be transmitted from particle to particle owing to the viscosity of the fluid.

With a solid between the surfaces, if the planes be relatively fixed whilst the material is under stress, the stress persists. On the other hand, in the case of a liquid the stresses very soon die away. The time required for this to take place, Maxwell called the "time of relaxation." For highly viscous liquids it may be measured by hours, or even days; for ordinary liquids a fraction of a second suffices; whilst for a gas such as air, Maxwell estimated the stress as lasting about the fifty-thousand millionth of a second.

The force R required to produce such continuous relative motion is a shearing stress, and it is measured by the stress per unit area of either of the planes, in which a is the length and b is the breadth of the area over which the force acts; and we may write

$$R = F a b \quad . \quad . \quad . \quad (1)$$

In Fig. 1 we have a mass of liquid $B_1 C_1$, $B_1 C_1$ for our purpose being regarded as free from the action of gravity, occupying the space between two horizontal parallel planes, XX and YY. The plane YY is moving under the action of a force, R. Let the distance between the planes be denoted by $r_\circ$ and the speed at which the plane YY is moving by V_1. Then the rate of distortion may be written—

$$\frac{V_1}{r_\circ} \quad . \quad . \quad . \quad . \quad (2)$$

Making s the velocity of any plane, at the distance r from YY we have

$$\frac{s}{r_\circ - r} = \frac{V_1}{r_\circ} \quad . \quad . \quad (3)$$

which expresses the fact that the rate of distortion is uniform across the section.

To maintain this rate of distortion a shearing stress F, acting parallel with the planes, is required. The ratio of this force to the rate of distortion, the temperature and pressure being unaltered, is

a constant for each particular liquid. It is denoted by μ, and is called the coefficient of viscosity. We may consequently make

$$F = \mu \frac{V_1}{r_0} \quad . \quad . \quad . \quad . \quad (4)$$

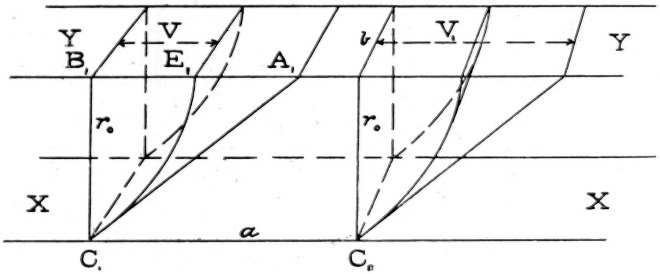
and

$$\mu = F \frac{r_0}{V_1} \quad . \quad . \quad . \quad . \quad (5)$$

It will be seen that as long as V_1 and r_0 retain the same relative proportions, *i.e.* as long as the rate of distortion is unaltered, the shearing stress F has the same value at all planes parallel to XX and YY.

In these illustrations no slip at the boundaries has been regarded as taking place.[1] In the case of such fluids as have had their viscosities determined by their rate of flow through capillary tubes, slipping at the boundaries, if it took place at all, must have been less than a thousandth of the mean flow, although the tangential force at the boundary was as much as 6 lbs. per square foot at a speed of 1·23 feet per second. Considering that the skin-resistance of a steamer going at 25 knots is not 6 lbs. per square foot, it is clear that slipping at the boundaries does not take place in practice, unless in very exceptional cases. The resistance to slipping at the

Fig. 2.



boundaries is in most cases probably greater than is the resistance to local shear of the liquid itself. In the case of ice the conditions are usually very different. Below the freezing point the ice may adhere to the boundary walls, and under such circumstances there is no slipping. But above the freezing point ice is always separated from other substances by a film of water, and as the viscosity of water is very much less than that of ice, slipping at the boundary readily takes place. Two surfaces of ice under the same conditions cohere strongly. This makes it impossible under such conditions for one portion of ice to flow over another portion resting in a hollow without imparting motion to it, for regelation takes place and the stresses are transmitted by the viscous resistance. It is

[1] "Dynamical Theory of Incompressible Fluids," by Osborne Reynolds, Phil. Trans. 1895, p. 123.

quite possible that the coefficient of viscosity μ is not a constant for glacier-ice, as such ice varies much in structure at different points, and its viscosity appears to be rather a molar than a molecular phenomenon. At present we do not appear to have any complete theory of viscosity; consequently it would be premature to declare that glacier-ice is not truly viscous. Before we can safely go so far we must be able to show that the same theory will not apply, for example, to both ice and water.

In Fig. 1 we have regarded the flow as resulting from the action of a stress applied at a plane surface parallel to the direction of flow, the viscosity of the fluid setting in motion the whole mass in such a way that the rate of distortion is everywhere the same.

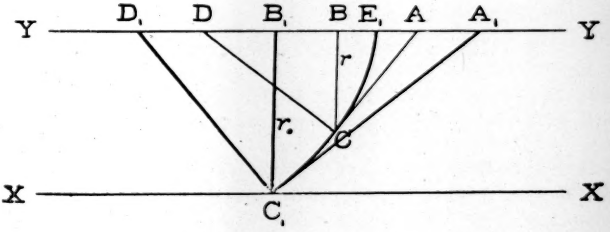
In Fig. 2 the viscous liquid is supposed to be flowing over a plane surface under the action of a uniform pressure acting upon a surface at right angles to the direction of flow. Here in place of a force F acting on unit area of $Y\,Y$ parallel to the direction of motion, we have a pressure P, acting on unit area of the surface $b\,r_0$ normal to the direction of flow. This may be due either to the pressure of a liquid column, or it may be regarded as the effect of gravity acting with an equal force on each particle of the liquid, the lower plane being inclined so as to give uniform conditions of flow between the parallel planes $X\,X$ and $Y\,Y$. In either case the nature of the flow is the same.

At the bounding plane $X\,X$ the whole pressure on $b\,r_0$ is acting to distort the liquid, and the rate of distortion

$$\frac{V_1}{r_0}$$

is the same as before for the same total force acting on the liquid. However, at any given distance r from the surface $Y\,Y$ the shearing stress is obviously proportional to the area acted on by the pressure, divided by the length of the line over which the shearing stress acts, *i.e.* to $\frac{b\,r}{b}$ or simply to r.

FIG. 3.



In Fig. 3, $B\,C = r$, and $\frac{A\,B}{B\,C}$ = rate of distortion at the point C; $\frac{A\,B}{B\,C}$ is, therefore, proportional to $B\,C$.

But by drawing CD, C_1D_1 perpendicular to CA, C_1A_1 we have by similar triangles

$$\frac{AB}{BC} = \frac{BC}{BD} \quad . \quad . \quad . \quad . \quad (6)$$

therefore $\frac{BC}{BD}$ is proportional to BC, and BD must be a constant, which is a characteristic property of the parabola. Hence the curve C_1CE_1 is a parabola whose axis is YY.

So we find that when a viscous substance is flowing under the action of gravity, or is propelled by a pressure uniformly distributed over a section normal to the direction of flow, the shearing stress is always greatest at the boundary. This is so even when the moving mass passes over a hollow with gently sloping sides. In Fig. 2 we may suppose that we are dealing with the flow of a very broad glacier moving down an incline. Every particle of it is being urged along in the direction of the inclination of the upper surface with a force depending upon the mean slope of the surface area immediately above it. The slope of the surface upon which it rests is only of secondary importance. The motive power wholly results from the inclination of the upper surface. If it were due to the slope of the lower surface a mass of ice in a basin-shaped hollow would form a vortex ring, and we should have a case of perpetual motion. Indeed, we must regard a glacier as moving just as a river does when the slope is very small (insufficient to make sinuous motion take the place of direct motion), but owing to its greater viscosity as moving at a much slower speed.

At each cross-section the volume passing must be the same, provided no ice is melted at the surfaces. Where the ice is thickest the slope of the upper surface is least, and where thinnest the slope is greatest. That this is so can be seen from the simple equations applicable where inertia does not influence the result.

Writing R as the total force on the liquid we have, Fig. 2,

$$R = Pr_\circ b \quad . \quad . \quad . \quad . \quad (7)$$

At the bounding plane XX, and making P the pressure on unit area, we have from equations (1) and (4)

$$R = \mu a b \frac{V_1}{r_\circ} \quad . \quad . \quad . \quad (8)$$

$$\therefore V_1 = \frac{R r_\circ}{\mu a b} \quad . \quad . \quad . \quad (9)$$

Making V the maximum velocity, as the curve of distortion is a parabola, we have $V = \frac{1}{2} V_1$, and from (9) and (7)

$$V = \frac{R r_\circ}{2 \mu a b} \quad . \quad . \quad . \quad (10)$$

$$= \frac{P r_\circ^2}{2 a \mu} \quad . \quad . \quad . \quad (11)$$

Also the volume V_1 swept through by any cross-section in unit of time

$$= \frac{2}{3} V b r_\circ$$

$$= \frac{2}{3} \cdot \frac{P r^2}{2 a \mu} \cdot b r_\circ$$

$$= \frac{P r_\circ^3 b}{3 a \mu} \quad . \quad . \quad . \quad (12)$$

So the volume passed is directly proportional to the pressure P, and to the cube of the thickness $r_\circ$ in the case of the central portion of a very wide glacier.

If the bed be semicircular we obtain in a similar way

$$V_1 = \frac{\pi}{16} \cdot \frac{P r^4}{a \mu} \quad . \quad . \quad . \quad (13)$$

No account is taken of the volume passed owing to slipping at the boundary. It, however, is only a fraction of that passed owing to the viscosity of the ice.

Experiments employed to ascertain the conditions of motion of existing glaciers have proved that velocity curves drawn across the glacier are parabolas, distorted somewhat where the ice-river is caused to make a bend, much in the same way as are the curves illustrating the flow of a river by the momentum of the water.

Above Montanvert the Mer-de-Glace is fractured across at one point, and into the crevasses so formed the surface moraine falls and forms imbedded strings of stone and mud. Lower down the melting of the ice at the surface again exposes the débris. But instead of running as straight lines across the glacier, the lines of débris sweep across as great parabolic curves having their apices pointing down-stream. No finer illustration of the fact that glacier-flow is a strictly viscous phenomenon could be conceived than is here presented. Proofs have also been given that a glacier moves more rapidly at the surface than it does at the bottom.

We also find that the rate of distortion at the bounding surface, where it rests upon rock, is greater than at any other point, and that there the abrading action is most energetic. Indeed, at the bottom of a hollow which might form the bed of a lake, even if the motion of the ice be slow, the pressure is very great, the ice going down into it at one end and rising from it at the other. Even at the bottom of such a hollow the maximum rate of distortion is located and a powerful grinding action maintained.

Throughout its course a glacier is urged along, not by a pressure from above but by gravity acting upon each molecule of ice during its whole course from the cold snow-fields above to the point where it melts in the warm valley below. No doubt *thrust* does play some part in the movement, just as does the momentum of the water in the flow of a river; but it is quite a subordinate feature and only produces local effects.

I am much indebted to Mr. C. E. Wolff, B.Sc., for the assistance he has rendered in the mathematical treatment of the subject.

VII.—On the Pitch Lake of Trinidad.[1]

By S. F. Peckham.

AFTER a recent visit to Trinidad I am led to add my testimony to that of the numerous observers, who for more than a hundred years have written concerning this remarkable phenomenon.

The earliest account of a visit to Trinidad, accessible to English readers, was published in the Transactions of the Royal Society of London in 1789, by Alexander Anderson.[2] He describes Point La Brea as a promontory fifty feet high jutting into the Gulf of Paria. Ascending to the lake he describes it as three miles in circumference, divided into "areola" resembling those upon a turtle's back, the surface of each being "horizontal and smooth." He was there in the rainy season, and concluded that evaporation on the clear afternoons removed the torrents of water that fell during other parts of the day, as there was no other outlet. He further states that the soil around La Brea consists of cinders and burnt earth, being evidently the product of subterranean fires, as there were hot springs in the neighbouring woods.

The next visitor is Dr. Nicholas Nugent, who published an account of a visit made in October, 1807.[3] He landed on the south side of La Brea Point, which he describes as consisting of a bluff of porcelain jasper, "generally of a red colour." Ascending to the lake he perceived a strong sulphurous and pitchy smell, like that of burning coal, and soon after had a view of the lake, which at first sight appeared to be an expanse of still water, frequently interrupted by clumps of trees and shrubs, but on a nearer approach it was found to be a plain of mineral pitch with frequent crevices filled with water. "The surface of the lake was not polished or smooth so as to be slippery; the consistence was such as to bear any weight, and it was not adhesive; though it partially received the impression of the foot, it bore us without any tremulous motion whatever, and several head of cattle were browsing on it in perfect security. The interstices or chasms are very numerous, and, being filled with water, present the only obstacle to walking over the surface. The arrangement of the chasms is very singular: the sides are invariably shelving from the surface, so as to nearly meet at the bottom, but there they bulge out towards each other with a considerable degree of convexity. These crevices are known occasionally to close up entirely, and we saw many marks or seams from this cause. The lake contains many islets covered with long grass and shrubs. It is not easy to state precisely the extent of this great collection of pitch; the line between it and the neighbouring soil is not always well defined. The main body may perhaps be estimated at three miles in circumference; the depth cannot be ascertained, and no subjacent rock or soil can be discovered. The negro houses in the vicinage, built by driving posts into the earth, frequently are

[1] From the Amer. Journ. Sci.—Third Series, vol. L, No. 295, July 1895.
[2] Philosophical Transactions, lxxix, 65, 1789.
[3] Transactions of the Geological Society of London, i, 63, 1811.

twisted or sunk on one side. In many places it seems to have actually overflowed like lava, and presents the wrinkled appearance which a sluggish substance would exhibit in motion. In some parts it is black, with a splintery or conchoidal fracture; in other parts so much softer, as to allow one to cut out a piece in any form with a spade or hatchet, and in the interior it is vesicular or oily; this is the character of by far the greater portion of the whole mass: in one place it bubbles up in a perfectly fluid state, so that you may take it up in a cup."

"In the south-eastern part of the island there is a similar collection of this bitumen, though of less extent, and many small detached spots of it are to be met with in the woods; it is even said that an evident line of communication may thus be traced between the two great receptacles."

Dr. Nugent devotes considerable space to a discussion of the geology and origin of the bitumen. As his opinions are based on theories no longer accepted by geologists, I will only remark *en passant* that he associates the mud volcanoes of Cedros Point with the agencies that have been active in bringing the bitumen to the surface.

The next notice that appeared was written in September, 1832, by Capt. J. E. Alexander, 42nd Royal Highlanders.[1] He says: "At the small hamlet of La Braye a considerable extent of coast is covered with the pitch, which runs a long way out to sea, and forms a bank under the water. The Pitch Lake is situated on the side of a hill; a gradual ascent leads to it, which is covered with pitch in a hardened state, and trees and vegetation flourish upon it. The pitch at the sides of the lake is perfectly hard and cold, but as one walks off towards the middle with shoes off, in order to wade through the water, the heat gradually increases, the pitch becomes softer and softer, until at last it is seen boiling up in a liquid state, and the soles of the feet become offensively warm. During the rainy season it is possible to walk over the whole lake, nearly, but in the hot season a greater part is not to be approached. The lake is about a mile and one-half in circumference; and not the least extraordinary circumstance is, that it should contain eight or ten small islands, on which trees are growing close to the boiling pitch. In standing for some time on the lake near the center, the surface gradually sinks until it forms a great bowl, as it were; and when the shoulders are level with the general surface of the lake, it is high time to get out. The flow of pitch from the lake has been immense, the whole country round, except near the Bay of Guapo, being covered with it; and it seems singular that no eruption has taken place within the memory of man, although the principle of motion still exists in the center of the lake."

Speaking of Point Cedros, he says: "What renders this point so interesting to the stranger is an assemblage of mud volcanoes, of which the largest may be about one hundred and fifty feet in diameter. At times the old craters cease to act, but when that

[1] Journal of the Franklin Institute, 1833, xv, 337. New Edinburgh Philos. Magazine.

is the case new ones invariably appear in the vicinity. The mud is fathomless, yet does not overflow, but remains within the circumference of the crater. From what I recollect of the Crimea, I should say that there is a remarkable similarity between it and Trinidad—geologically speaking: in both there are mud volcanoes, in both there are bituminous lakes, and both have been frequently visited with earthquakes."

The next observer was Mr. N. S. Manross, who visited the lake in 1855, and has been widely quoted. He says: "The village of La Brea stands on a projecting tongue of land which owes its preservation from the inroads of the sea to the fact that it consists entirely of hardened pitch, which withstands the waves far better than the loose materials of the accompanying formations. The shore for miles, both north and south, consists mainly of the same material, and juts boldly out into the sea wherever it is thus pitch-bound. A road leads up from the landing to some sugar estates beyond the lake. It ascends a gentle slope of hardened pitch, which, where left to itself, is covered with a dense growth of reeds and bushes. The road itself is a fine illustration of the adaptation of pitch to the purpose of paving. Where too much mixed with earth it has become pulverized to a depth of a few inches, but in many places it is still so pure and solid that the wheels of heavily loaded sugar wagons and the hoofs of horses make but a slight, and even that a transient, impression. In no part of the ascent to the shore of the lake does the stream of pitch appear to be covered by more than one or two feet of soil, while in most places it is entirely bare. In places where the surface is not protected by vegetation it becomes so far softened by the sun as to be still making progress downward.

"On nearing the lake the ascent becomes steeper. Here the pitch is bare, or but slightly covered with grass. Its appearance is not that of a sudden simultaneous overflow in a single smooth stream, but that of a great number of streams each but a few yards or rods in breadth. Their surfaces are drawn out into all manner of contortions, and where the edges meet, small ridges have been thrown up and the pitch broken into fragments not unlike the scoriæ of lava currents. These fragments of pitch were on fire in several places, having been kindled by a fire that ran through the 'bush' a few weeks before."

"On ascending the last slope of this pitchy glacier a singular scene meets the eye. A black and circular plain of pitch one-half mile in diameter lies flush with the edge of the stream. It is surrounded by a dense wall of forest, in which various species of tall palm are most conspicuous. The lake itself is entirely bare of vegetation, except about twenty small clumps of trees which are arranged in a sort of broken circle about one-half way from the center to the circumference."

"The entire surface of this circular plain is seen to be interspersed by a network of water channels. Its appearance is exactly that of marbled paper. The pitch is divided into flat or slightly convex areas, mostly polygonal but sometimes circular. They vary from

one to eight rods in diameter. The intervening spaces are full of water. These channels (or spaces) have heretofore been described as crevices or cracks in the pitch. This description, however, is incorrect, for the material, though apparently almost as hard as stone, is yet far too plastic to admit of anything like a fissure remaining open in it. The channels are produced and maintained by the following singular process. Each of the many areas into which the lake is divided possesses an independent revolving motion in this wise: at the center of the area the pitch is constantly rising up, not breaking out in streams, but rising *en masse*. It is thus constantly displacing that which previously occupied the center, and forcing it towards the circumference. The surface becomes covered with concentric wrinkles and the interior structure somewhat laminated. When the edge of such an expanding area meets that of the adjoining one the pitch rolls under, to be thrown up again at the center at some future period. The material is nearly soft enough to meet and form a close joint at the top, but descends with a rounded edge and at a considerable angle. The conclusion, then, to which a close observation leads us in regard to the present condition of this singular lake is, not that it has suddenly cooled down from a boiling state, as heretofore described, but that, as the material is, it is still boiling, although with an infinitely slow motion. As the descent of the glacier may be considered the slowest instance of flowing in nature, so the revolutions of the scarcely less solid bitumen of this lake may be set down as the slowest example of ebullition."

"Towards the center of the lake several detached areas are met with, the surfaces of which yield under the foot. On standing ten or fifteen minutes one may find himself ankle deep. A person standing long enough would undoubtedly sink and perhaps disappear in it; but in no place was it possible to form those bowl-like depressions around the observer as described by former travellers."

"The water which filled the crevices of the pitch is clear and very pure. It is the favourite resort of all the washerwomen for miles around. As the water is flowing now, the pitch has formerly flowed from the lake in all directions. The entire surface covered by it is estimated at 3000 acres. The pores of the pitch are full of water, which oozes out on the slightest pressure, and by moistening the skin prevents adhesion. Streams of gas issue, sometimes rising through the water, but more frequently from small openings in the pitch above water-level."

"In one of the star-shaped pools of water, a column of pitch had been forced up from the bottom, expanding into a sort of center-table about four feet in diameter. Pieces torn from the edge of this table sank readily, showing that it had been raised by pressure and not by buoyancy."

"About a mile and one-half south of the lake I observed numerous beds of indurated clay filled with the remains of leaves and vegetation. A little further on appears a bed of brown coal and lignite, about twelve feet thick. It has such a dip and direction that, if

continuous, it would pass under the lake at a great depth. At about a mile to the north-west of the lake another bed of brown coal crops out upon the shore. It is about twenty feet thick. From the occurrence of such considerable accumulations of vegetable matter, so situated as apparently to pass under the lake, it seems reasonable to regard them as the source of the pitchy matter. Indeed, many pieces of wood may be observed in the beds of brown coal, which differ in no respect in their appearance from many of the pieces thrown up in the lake itself."

Mr. Manross[1] is completely at sea in his points of the compass.

The observations upon which the descriptions of this lake, from which I have made careful abstracts, were based, were made from forty to one hundred and sixty years ago. I have been able to verify them in almost every particular, and these descriptions clearly portray the appearance and condition of the lake at the time I visited it in March, 1895. In addition to these descriptions, other observations quite different in character and purpose have been made concerning the island of Trinidad, and incidentally of the Pitch Lake, during the last thirty-five years. In 1860 Messrs. Wall and Sawkins published quite an extended report upon the geology of Trinidad, including observations upon the occurrence of bitumen throughout the island.[2]

Dr. Nugent remarked in the article above quoted: "and it must be remembered that geological enquiries are not conducted here with that facility with which they are in some other parts of the world; the soil is almost universally covered with the thickest and most luxuriant vegetation, and the stranger is soon exhausted and overcome by the scorching rays of the vertical sun."[3] These observations exactly express the conditions under which these gentlemen performed their undertaking. It is, therefore, not surprising that errors should have been found in their conclusions and corrected by later observers.

Mr. J. R. Lechmere Guppy, in 1892, thus stated the conclusions that he had reached in reference to Trinidad Geology[4]:—

"It appears from the evidence derived from the nature of the Naparima rocks, their fossil contents, and the movements which

[1] American Journal of Science, part ii, vol. xx, p. 153, 1855.

[2] Report on the Geology of Trinidad, by order of the Lords Commissioners of Her Majesty's Treasury, London, 1860.

[3] *Loc. cit.*, p. 70.

[4] Quart. Journ. Geol. Soc. 1892, vol. xlviii, pp. 519–536. *Ibid.*, vol. xxii, 571; *ibid.*, vol. xxiv, p. 11; *ibid.*, vol. xxvi, p. 413; *ibid.*, vol. xlviii, p. 221.

The "Naparima rocks" consist of an anticlical that, abutting in a bluff near San Fernando, on the Gulf of Paria, extends across the island almost to the east coast. They also appear on the mainland of Venezuela near the Bay of Cumana. The lowest strata are Cretaceous, and are called, together with the Eocene above them, the "Older Parian." The "Newer Parian" above is Miocene, and contains lignites and bitumen. Here orbitoides and nummulites are found in a mass of rock projecting into the Gulf of Paria, supposed to be Miocene. In the Western Hemisphere orbitoides are supposed to characterize the Eocene. In the Eastern Hemisphere nummulites are characteristic of the same formation. The deposit that here contains them both lies between other Miocene deposits.

have effected them and other formations of Trinidad, that during the Cretaceous and Eocene periods there was a sea having a considerable but variable depth of water, say up to one thousand fathoms and more. It is probable that this sea extended on the north to the base of the northern range of hills, a distance of some twenty or twenty-five miles from the northern limit of the Naparima deposits. During the Cretaceo-Eocene period the northern mountains probably formed an unbroken chain with the littoral cordillera of Venezuela. This chain may be called the 'Parian Range.' According to abundantly clear evidence given by me in 1877,[1] the great chasms between Trinidad and Venezuela called the Bocas del Drago were produced by subsidence. Previous to this the 'Parian Range' probably formed the southern boundary of the Caribbean continent, and was a barrier through which no large river found its way. The 'Parian Range' may be regarded as one of those 'stable areas' which has never been submerged since Palæozoic times."

"To the westward the Cretaceo-Eocene sea probably extended as far as the present low-lying alluvial plains of Venezuela. In this direction it was no doubt bounded by the high lands now forming the Pico de Cumanacoa and the Cerro del Bergantin, ranges at present twice as high as any in Trinidad. Its southern extension went presumably near to the granitic and gneissic ranges and plateaux of Guiana."

"After the close of the Miocene period there was probably in the region south of the 'Parian Range' a slow and gradual upheaval which brought the oceanic deposits above the level of the sea, during which process they suffered great denudation. The Gulf of Paria was then land, and Trinidad was then united to the mainland. At that time the river Guarapiche probably flowed across Trinidad from Venezuela, while the Orinoco continued to pour its waters into the ocean at some distance southward. The disruption of the 'Parian Range' and the formation of the Bocas and the Gulf of Paria followed. There are palæontological reasons for believing that this submergence did not take place until a late geological epoch."

From this conclusion it is manifest that the Miocene period was one of frequent alternation of elevation and submergence, during which there were long periods when the different members of the formation were covered with tropical swamps having luxuriant vegetation, that are now represented by the great swamp at the east end of the island. The buried vegetation of these swamps has been converted into coal through Pliocene and recent times, which has been distilled at low temperatures, probably initiated by fermentation within the mass of the coal itself, assisted by the water of thermal springs.

Messrs. Wall and Sawkins discuss at length the phenomena peculiar to the lake, and disagree with previous observers to such an extent that, after a careful examination of their paper, I am forced to the conclusion that their study of the subject was

[1] Proc. Sci. Assoc. Trinidad, December 1877, p. 103.

extremely superficial. In illustration: they say of the "areas," "the surface is frequently marked with ridges, especially near the edges: these are due to the constant expansion and contraction which is supposed to occur." A most singular explanation, resting on *supposed* phenomena that were neither observed nor proved theoretically. Although they quote Bischoff,[1] it is only to prove a possible origin for the asphaltum by direct conversion from woody fibre, leaving entirely out of consideration the conclusions of this eminent author in reference to the production of hydrogen sulphide, to which further reference will be made. It is, however, just to these authors to remark that the general knowledge of the world concerning bitumens and their origin has been vastly increased during the thirty-five years that have elapsed since they issued their report.

Diagram-map of the Island of Trinidad.

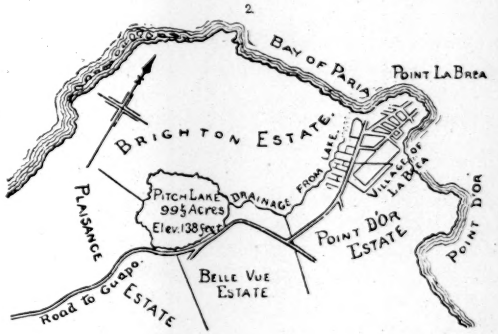
Charles Kingsley and some others have written descriptions of the lake since 1860, but no new facts are stated by them.[2]

During 1892 the Hon. W. P. Pierce, then United States Consul at Port of Spain, at the request of the department, made a very full and able report upon the asphalt of Trinidad.[3] The fulness with which all sources of information are made to lend their quota towards a general conclusion in regard to all possible aspects of this question, is of itself the best guarantee, to any unprejudiced reader, of the eminent fairness of this report. Its appearance was almost immediately followed by another report made by Mr. Clifford Richardson, at that time Inspector of Asphalt and Cement for the District of Columbia.[4]

[1] Bischoff, Chem. and Phys. Geol. (Cav. Soc. Ed.), vol. i, pp. 288, 290, 291.
[2] "A Christmas in the West Indies." London, 1879.
[3] Consular Reports, No. 145, Oct. 1892.
[4] Reports of the operation of the Engineer Department of the District of Columbia, for the fiscal year ending June 30th, 1892. Washington, 1893.

This report of Mr. Richardson, while seemingly emanating from a wholly disinterested source, presents statements and conclusions in many respects quite different from those reached by Consul Pierce and previous observers. It was for the purpose of satisfying myself as to the facts, and also of studying the occurrence of bitumen in Trinidad in the light of such observations as I had made in California and elsewhere, that I lately made a trip to Trinidad and the Pitch Lake.

On approaching Point La Brea from the north-west, the reef of asphaltum that forms a barrier around the point and against the sea is plainly visible. Upon the point itself and jutting into the sea are what appear like low ledges of rock, which a nearer inspection proved to be masses of asphalt taken from village lots, that had been piled for shipment, but had been so long left in the tropical sun that they had melted and flowed into a solid homogeneous mass, that looked at a short distance off like ledges of slate. The piles,



Topography of the immediate area of the Pitch Lake of Trinidad.

which were originally about twenty-five feet in height, were not more than three feet thick. Near these masses were other piles of the same material, from which lighters were being loaded, and which had not remained in the sun long enough to melt. Many hundreds of tons were included in these masses, the original pieces of which had so far coalesced that the asphalt had to be again broken with a pick before removal. Passing on shore beyond these piles, the plant of the Pitch-lake Concessionaires was encountered, in which the operation of boiling a mixture of so-called land asphalt, the ordinary lake asphalt, and the soft pitch from the centre of the lake was going forward. The operation is conducted in kettles, resembling open sugar kettles, and is very crude and simple in character. Passing eastward I next encountered a wide area covered with asphalt, that had melted in the sun to a level surface, perhaps two feet in depth. I was told that this asphalt was dug from a village lot, the ownership of which was in dispute; that originally the piles were at least twenty feet in height, but while the owners disputed the piles melted in the sun.

Farther on I struck the road to the lake, which appeared to me exactly as Mr. Manross had described it forty years ago. The houses in the village were in the same condition described by Dr. Nugent in 1807. The slope leading up to the lake was in exactly the condition in which all previous observers had described it, as resembling a lava-flow—a black glacier. The several points at which asphalt had been and was being excavated, showed in the most admirable manner that the movement of the asphalt down the slope and towards the sea is still in progress. Every excavation was in a short time partially refilled by a movement of the asphalt up from the bottom and in from the sides, the cavity in time becoming filled full to the level of the surrounding area. One illustration of this fact was the spot from which the noted cargo of the Teneriffe was taken, every trace of former excavation having completely disappeared.[1]

The Trinidad Bituminous Asphalt Company were excavating a lot near the road, and had also recently uncovered a lot that had become almost completely refilled in a few months, after the removal of several thousand tons of asphalt. Farther up the slope the Trinidad Asphalt Company were taking out asphalt from lots on the Belle Vue estate. These lots, like most of the others, were covered with a dense tropical jungle, consisting of palms, sedges, canna, and other plants, from three to ten feet in height. It did not need the testimony of Mr. Manross to show that in all probability fire had more than once consumed this mass of vegetation, producing a terrific heat, that had melted and converted into so-called "iron-pitch" much of the surface of the pitch. The "iron-pitch" is present in greater or less quantity, both within and without the boundaries of the lake, wherever fire has consumed the vegetation, and consists simply of melted pitch which has been heated so hot as to deprive it of its water and more volatile constituents, causing it to flow in streams, often to considerable distances. Below these melted masses the pitch lies in its normal and unaltered condition.

It must, however, be constantly borne in mind, while reading the statements of different observers made on different occasions, that the lake and its principal overflow have presented different phenomena at different periods. While it was evident at the time I visited the overflow that fire had swept over its surface, it was equally evident that it had for a long time been free from any such visitation. I have seen similar flood-plains of asphalt in California that had been on fire for months, and others that had been burned some time previous to my visit to them. I can imagine that after such a fire the resemblance of the overflow of the lake to a "black glacier" would be much more pronounced than when covered with a rank growth of vegetation, as it now is. It is not, however, the surface that flows, covered as it is by masses of coke, iron-pitch, vegetation, and rubbish. The houses in La Brea now all rest on

[1] I was told by those who witnessed the digging of this cargo, that apparently no care was exercised in its selection. One gentleman declared that it was the dirtiest cargo of pitch ever sent from the island.

blocks. In this position they are much more stable than on posts, although anything resting upon the overflow is unstable. It is the cheese-pitch, full of water, and containing more or less gas, buried beneath these surface accidents, that has flowed and still flows.

Although a large amount of clay and vegetable débris fills the interstitial spaces of the rough surface of the asphalt, the vegetation is not confined to such surfaces, but seems to flourish equally well upon the bare pitch, the roots penetrating the pitch without the slightest difficulty, except where it had been converted by melting into iron-pitch. There is also considerable coke where the fires have been hottest. All of these impurities are carefully excluded from the pitch that is mined, both for boiling and for shipment in the crude state, by all of the men employed by the different companies in extracting it. This selection is not difficult, as the appearance of the iron-pitch is very different, and the amount very small, as compared with the pure or cheese-pitch.

(*To be continued in our next Number.*)

REVIEWS.

I.—The Cretaceous Series of the Upper Missouri; and the Chalk of North America and its Foraminifera.

SEVERAL interesting and instructive reports are published in the Iowa Geological Survey, vol. iii. Second Annual Report, 1893, with accompanying papers: 501 pages, with numerous maps, plates, cuts, and photographs. Large 8vo, Des Moines, 1895. There are: 1. Cretaceous deposits of the Sioux Valley; by H. F. Bain. 2. Certain Devonian and Carboniferous outliers in Eastern Iowa; by W. H. Norton. 3. Geological section along Middle River in Central Iowa; by J. L. Tilton. 4. Glacial scorings in Iowa; by C. R. Keyes. 5. Thickness of the Palæozoic strata of North-eastern Iowa; by W. H. Norton. 6. Composition of the Iowa Chalk; by S. Calvin. 7. Buried River-channels in South-eastern Iowa; by C. H. Gordon. 8. Gypsum deposits of Iowa; by C. R. Keyes. 9. Geology of Lee County; by C. R. Keyes. 10. Geology of Des Moines County; by C. R. Keyes.

I. At pages 101–114 Mr. Bain details the features and measurements of the Cretaceous series as seen along the Sioux River, a tributary of the Upper Missouri, forming the northern third of the western boundary of Iowa. Beneath a thick coating of drift and loess, he notes the occurrence (downwards) of—(1) the Pierre shale; (2) Niobrara chalks and soft limestone (locally unconformable on the Sioux quartzite); (3) Benton shale; and (4) Dakota sandstones and shales. These formations vary in their thicknesses over this part of America; and here are apparently some 300 or 400 feet thick. They correspond with the description given of this and neighbouring districts by Meek and Hayden (1853–1873), except that the topmost part of the series, namely, that of the Fox Hills (sandstones and arenaceous shales), is not shown on the Sioux River. Mr. Bain points out that the recognized eastward extension of the upper

members of the group renders it probable that the Mesozoic seas spread further eastward than has hitherto been commonly supposed.

II. At pages 211–236 Dr. Samuel Calvin, State Geologist, shows that the old idea of the geological structure of North America being destitute of "Chalk" is quite unfounded, as readers of the American Journal of Science, Canadian Naturalist, Bulletin of the American Geological Society, Science, the Reports of several Geological Surveys, and well-known works by Ehrenberg and F. Römer, might well know. He states that true "Chalk," soft and white, made up of Foraminifera and Coccoliths, and without the admixture of mechanical sediments, has a thickness of at least 25 feet on the Sioux River in Iowa; and is 50 feet thick at Ponca in Nebraska; at Saint Helena, further up the Missouri, 90 feet; at Yankton in South Dakota, 130 feet; and probably 200 feet at the mouth of the Niobrara. Near the mouth of the Sioux it is represented by (from top)—(1) Chalk, 12 feet; (2) soft Inoceramus-limestone, 12 feet; (3) Chalk, 12 feet. (See Mr. Bain's memoir, p. 111.)

Dr. Calvin (p. 115), having described the mode of occurrence of the foraminiferal shells as being quite similar to that in the English Chalk, proceeds to enumerate and discuss the various published notices that have indicated a rising and increasing knowledge of this view, founded on the recognition of microscopic fossils in the Cretaceous strata from various parts of North America. Thus Prof. J. W. Bailey, in 1841, described some "prairie chalk" from the North-west (see also Hitchcock's "Elementary Geology," new edition, 1860, p. 382); Dr. Ch. G. Ehrenberg figured some Foraminifera from the Chalk of Missouri and Mississippi, 1843, and Bailey in 1844; Dr. F. Römer some from Texas, 1852, and T. A. Conrad in 1857; F. B. Meek and F. V. Hayden described the Cretaceous strata along the Missouri River, in 1859–61; Dr. C. A. White the Inoceramus-limestone of Iowa, in 1870; Dr. G. M. Dawson the Chalk of Nebraska and Manitoba, 1874; Prof. R. T. Hill, in 1888, 1889, and 1890, definitely gave the name of "Chalk" to the soft calcareous beds of the Lower and Upper Cretaceous series in Texas and Arkansas; and Prof. S. W. Williston treated of the Kansas Chalk in 1890.

The more common of the Foraminifera of the North-American Chalk, as figured by the various observers above referred to, appear to be—

1. *Textilaria pygmæa*, d'Orbigny. G. M. Dawson, Canadian Naturalist, vol. vii, 1874, p. 253, fig. *b*; S. Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 226, pl. xix, fig. 7. This is rather common in the Cretaceous and Tertiary deposits, and in existing seas.

2. *Textilaria globulosa*, Ehrenberg. Bailey, Amer. Journ. Sci. and Arts, vol. xli, 1841, p. 401, fig. 2; Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 225, pl. xix, fig. 5. This species, first described by Ehrenberg, has a wide geographical range, chiefly in the Cretaceous series. The localities whence the specimens figured by Ehrenberg were obtained are—Cretaceous: Egypt, Syria, Arabia (?), France,

England, Islands of Möen and Rügen in the Baltic, Bohemia, Russia, and Missouri; Eocene: Egypt, and Bavaria; also from volcanic mud in the Eastern Archipelago, and from wind-dust at Malta, Lyons, and Silesia or Austria. Dr. H. B. Brady has recorded it as occurring in a brackish tidal pond at Westport, Ireland. It is a common Cretaceous fossil, being recorded from the Chalk of Swanscombe (zone of *Micraster cor-testudinarium*), from the Chalk of Taplow (zone of *Belemnitella quadrata*); from the Chalk of Westphalia, by Reuss, under the name *T. globifera*; also by Andreae, from the Oligocene of Elsass, under the name *T. gracillima*; and by Millett from the Pliocene of St. Erth. One specimen has been met with in the Chillesford Beds of Aldeby, near Beccles.

3. *Textilaria gibbosa*, d'Orbigny. Bailey, Amer. Journ. Sci. and Arts, vol. xli, 1841, p. 401, fig. 1 (?); Woodward and Thomas, 13th Geol. Rep. Minnesota, 1885, p. 166. pl. iii, figs. 1–5 (as "*T. globulosa*"); Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 225 (as a small broad variety of *T. globulosa* widening rapidly in its growth, and, indeed, zoologically there is very little difference between these forms), pl. xix, fig. 6. This is a common *Textilaria*, both recent and fossil.

4. *Textilaria striata*, Ehrenberg. G. M. Dawson, Canad. Nat., vol. vii, 1874, p. 253, fig. *a* (given as "*T. globulosa*"). This is a variety of *T. gibbosa*. Among the figures of this form given by Woodward and Thomas in the Thirteenth Report of the Geological Survey of Minnesota, 1885, p. 166, pl. iii, figs. 1–5 (there termed "*T. globulosa*"), one *partially striated* individual is shown by fig. 5. This is more especially an American species.

5. *Spiroplecta Americana*, Ehrenberg. Mentioned by Bailey, Amer. Journ. Sci. and Arts, vol. xlvi, 1844, p. 308; but the figure in the footnote is possibly a *Textilaria*, not a *Spiroplecta*. Woodward and Thomas, Thirteenth Report Geol. Surv. Minnesota, 1885, p. 168, pl. iii, fig. 9. This species was at first regarded by Ehrenberg as a *Textilaria*; but its name was changed by him to *Heterohelix* in 1841; and in his "Mikrogeologie," 1854, he referred to it as *Spiroplecta Americana* from the Chalk of Missouri and Mississippi. Equivalent forms, not always arenaceous, are found in the European Chalk and Tertiaries, and in existing seas.

6. *Bolivina punctata*, d'Orbigny. A well-known subtypical form of *Bulimina*, under which generic appellation it appears in the Iowa Geol. Survey, vol. iii, 1895, p. 229, pl. xix, fig. 8. This is cosmopolitan in the oceans, from shallow to abyssal waters; and it is common in the Chalk and Tertiaries.

7. *Dentalina communis*, d'Orbigny. Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 229 ("Nodosarian forms"), pl. xix, figs. 11, 12, 13. Such Nodosarines occur in the Permian and Jurassic strata, and are extremely common in European Chalk, in the Tertiaries, and in many seas, from shallow to abyssal depths.

8. *Nodosaria ambigua*, Neugeboren. *Nodosaria Texana*, Conrad, Geol. Reports U.S. and Mexican Boundary Survey, vol. i, pt. 2 (4to, Washington, 1857), "Description of Cretaceous and Tertiary Fossils,"

p. 159, pl. xiv, figs. 4 *a*, *b*, *c*, corresponds very closely indeed with Neugeboren's *Nodosaria ambigua*, Denkschrift. k. Akad. Wiss. Wien, vol. xii, 1856, p. 71, pl. i, figs. 13–16, from the Chalk of Upper Lapugy in Transylvania. It occurs also in some Tertiary beds, and in the North Pacific Ocean.

9. *Frondicularia.* A fragment of *Fr. Verneuiliana* (?), d'Orbigny, is given by Dr. Calvin in pl. xix, fig. 14, p. 229, Iowa Geol. Survey, vol. iii. It is known from the Chalk of France and England.

10. *Cristellaria.* Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 229, pl. xix, fig. 9, is either one of the poor varieties of *Cr. rotulata*, such as are met with in the European Chalk, or the initial part of one of the many *Marginulinæ* of the Chalk. This is similar also to others of both kinds met with in older and younger strata.

11. *Globigerina cretacea*, d'Orbigny. Bailey, Amer. Journ. Sci. and Arts, vol. xli, 1841, p. 401, fig. 4; G. M. Dawson, Canad. Nat., vol. vii, 1874, p. 253, fig. *c* ("*Discorbina globularis*," possibly an immature *Globigerina digitata*); Woodward and Thomas, Geol. Surv. Minnesota, 1885, p. 171, pl. iii, figs. 13 (?), 14–16; pl. iv, fig. 19, and edge-views, figs. 23 and 24 (?); Calvin, Iowa Geol. Survey, vol. iii, 1895, pp. 216, 228, pl. xix, figs. 1, 2, 4. The appearance of limbate borders in these last and in most of the other figures on this plate is probably due to the translucent edges of these shells, as seen when mounted in balsam. Specimens of real *Globigerina marginata* (Reuss), such as are known in the European Chalk, were figured by Woodward and Thomas in the Geol. Survey, Minnesota, 1885, p. 174, pl. iv, figs. 20–22, from the Boulder-clay containing Cretaceous Foraminifera. *Globigerina cretacea* is a characteristic microzoon of the Chalk. It has near relatives in other deposits and in the existing seas.

12. *Globigerina digitata*, Brady. Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 228, pl. xix, fig. 3. This interesting species has not been previously observed in the Chalk, but only in the present oceans. G. M. Dawson's fig. *c*, however, above mentioned, with its elongate ultimate chamber, may be a proximate variety, or a young form.

13. *Anomalina ammonoides* (Reuss), G. M. Dawson, Canad. Nat., vol. vii, 1874, p. 253, fig. *d* ("*Planorbulina Ariminensis*"), is one of the neat and almost symmetrical forms belonging to *Planorbulina*; it is very common in the European Chalk, and lives in the sea now at depths varying from 37 to 1350 fathoms. It is figured by Dr. Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 235, pl. xix, fig. 10, as "*Truncatulina*," to which it is generically allied, but more symmetrically formed.

14. *Orbitolina* or *Patellina lenticularis* (Blumenbach) is probably the foraminifer, from Texas, figured and described by Dr. Ferdinand Römer as *Orbitulites Texanus* in the "Kreidebildung von Texas," etc. (4to, Bonn, 1852), p. 86, pl. x, figs. 7 *a–d*. He first mentioned it in his "Texas" (Bonn, 1849), p. 392.

For the occurrence of this little Cenomanian fossil in Europe, see the Catalogue of the Fossil Foraminifera in the British Museum

(Natural-History Branch), 1882, pp. 10, 17, and 19; and for its synonomy and relationships, pages 84, 85.

At pages 228, 229, Dr. Calvin offers some suggestive remarks on the probable conditions of that part of the Cretaceous sea now replaced by North America, especially in the Iowa region, as to the relative depth and clearness in some parts, and its shallower state near the old shore-line eastward. Judging from the relatively large growth, or the contrary, of some *Textilariæ* and other forms, he indicates the area of deep and clear water, and that of shallow and littoral with its mechanical sediments. We cannot, however, agree with his notion that the *Globigerina digitata* is an "abnormal" form, taking on an extra growth in consequence of being "restricted" or otherwise on the deep sea-bottom.

The successive formation of the several members of the Cretaceous series in this region, and the probable physical conditions under which they were deposited, is carefully described. The local subsidence was greatest when the Niobrara Chalk was being formed, with its abundant Foraminifera, whether pelagic or abyssal, and with the associated Coccoliths and Rhabdoliths as in Manitoba. Then a gradual elevation of the sea-bottom began; and this in time brought about the formation of the shales and sandstones of the Pierre and succeeding stages.

The wide range of these Foraminifera in the two Hemispheres is a subject of interest not lost sight of by Dr. Calvin; and their long continuous and persistent existence, or great range in time, has been often noticed by naturalists. T. R. J.

II.—Grundzüge der Palæontologie (Palæozoologie). Von Karl A. von Zittel, Professor an der Universität zu München. 972 Textseiten, mit 2048 in den Text gedruckten Abbildungen. München u. Leipzig. (Oldenbourg, 1895.) London: Dulau and Co., 37, Soho Square, W. Price 25*s.*, post free.

IT is not more than two years since that Prof. von Zittel brought to a successful conclusion the "Handbuch der Palæontologie," which, on a scale not before attempted, included in its scope a description of all the leading genera of fossils, as well as references to those of subordinate importance. In the preparation of this immense work, nearly twenty years ran by; and, as is well known, in this interval our knowledge of fossils advanced in nearly every department, with the result that by the time the concluding volume of the "Handbuch" appeared, the earlier portion of the work, treating of the lower groups of the Invertebrata, was already in part out of date. In place, however, of re-writing the first volume of the "Handbuch" as an instalment of a new edition, Von Zittel has prepared the present "Grundzüge," in which a brief but comprehensive representation of the more important facts of palæontology, both vertebrate and invertebrate, have been brought within the compass of a single volume. The same method of arrangement has been adopted in this, as in the larger work; but to keep it within the necessary limits, a selection of the specially typical forms

had to be made for description, while others are referred to by name only. The author has endeavoured to carry out, what should be the leading aim of palæontology, a natural system corresponding to morphological and phylogenetical facts. Fossils are regarded chiefly in their relations as members of the animal kingdom, rather than from the geological standpoint as furnishing evidence of the comparative age of the beds in which they are inclosed; but their significance in this latter respect has by no means been neglected, and the geologist will find the characteristically leading fossils of the different rock formations amply described and figured.

A special feature of this volume is the unusual number and excellence of the illustrations, which adorn nearly every page; not only has full use been made of the clichés of the remarkably clear woodcuts of the "Handbuch," but there are in addition numerous fresh figures, so that a typical form of nearly every fossil genus of importance has been represented.

In an introductory chapter, after an explanation of the conception and object of the science of Palæontology, reference is made to the chemical and mechanical changes which take place in organic remains in the process of fossilization, and this is followed by an instructive and spirited exposition of the relations of Palæontology to each of the sister sciences of Biology, Geology, Physical Geography, Embryology, and Phylogeny, and the essential importance and value of the facts contributed by Palæontology to these respective sciences is very forcibly elucidated.

It would lead beyond the bounds of our space to refer in any detail to the numerous alterations and additions which have been introduced in the systematic portion of the present work, in comparison with that of the "Handbuch": these mainly concern, as might be supposed, the division of the Invertebrata. It will suffice to state, however, that the results of the most recent investigations of specialists and others in the various groups of fossils have been critically noted and incorporated in this book, thus rendering it valuable as a reference to the experienced palæontologist as well as to the student-beginner in the science.

As additional recommendations, the letterpress is clear, the book is strongly bound, and it is brought out by the publishers at a very moderate price.

III.—Observations on the Structure of some Diprionidæ. By St. Leonk. Törnquist. Trans. Roy. Swedish Physiographical Soc., 1892–93.

THE author in this paper describes the structure of *Climacograptus scalaris* (Lin.), *C. internexus* (Törnq.), *Diplograptus palmeus* (Barr.), *D. bellulus* (Törnq.), and *Cephalograptus cometa* (Geinitz). His method of preparation consists in grinding down specimens preserved in iron pyrites until the required section is obtained. For purposes of description he divides the thecæ of the polypary into two series: (*a*) primordial, containing the first theca; (*b*) second series.

He believes that the polypary of *Climacograptus scalaris* is built up in the following way: The conical sicula is on the side of the second thecal series, and the apex coincides with the axis of the polypary. It sends out the connecting canal on the side facing the primordial series, and this runs along the lower portion of the sicula and opens into the proximal part of the biserial chamber. This chamber he defines as that part of the common canal below the median septum; it gives rise to two thecæ on each side, the rest of the cavity of the rhabdosoma being divided by a median septum into two uniserial canals originating in a common chamber.

Climacograptus internexus is similarly developed, but is characterized by the free prolongation of the lower lamina of each thecal partition, which extends downwards over the aperture in a manner resembling *M. priodon* (Bronn). The median septum is undulated.

Diplograptus palmeus.—The septum is incomplete, and thecal series therefore originate from one biserial canal.

D. bellulus.—This species is characterized by the long proximal prolongation of the virgula. There is no trace of a median septum, and the common canal is very narrow.

Cephalograptus cometa.—The connecting canal is almost at the base of the sicula, and is directed somewhat outwards. It opens into the common biserial canal, which does not send out the first theca of the second series until far beyond the pointed end of the sicula. The median septum is incomplete.

The author concludes with the observation that the central cavity of the rhabdosoma may consist of two uniserial canals, separated by a more or less complete median septum, and originating from a short biserial chamber, or a single biserial canal.

G. L. E. and E. M. R. W.

IV.—"Ueber Diplograptidæ," Lapw., and "Ueber *Monograptus*," Geinitz. By Carl Wisman. Bull. Geol. Instit. of the Univ. of Upsala. Vol I, No. 2. 1893.

THE author has been able to make very complete researches on the structure of the proximal part of the polypary in the Diplograptidæ and in *Monograptus*, owing to the method of preservation of his specimens. The polypary was embedded in limestone, and was isolated and stained by means of acid and Schulze's macerating fluid.

As regards the Diplograptidæ, Wisman lays stress on the following points: The sicula consists of two parts, the proximal and distal, differing in their form and external sculpture. This gives rise, on the right-hand side, to only *one* bud, so that the Diplograptidæ are Monoprionidian. This bud gives rise to a theca, and each subsequent theca develops from the one next below it, but on the opposite side and not from a common canal. The polypary, together with the virgula, develop at first both proximally and distally, but at a later period the distal growth alone persists. The sicula does not lie embedded between two branches grown together along their dorsal surfaces, as was formerly supposed to be the case, but is at